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Kilibarda

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(54) **MODULAR VEHICLE ASSEMBLY SYSTEM AND METHOD**

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(52) **U.S. Cl.**
CPC **B62D 65/022** (2013.01); **B23K 11/115** (2013.01); **B23K 11/3063** (2013.01);
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(58) **Field of Classification Search**
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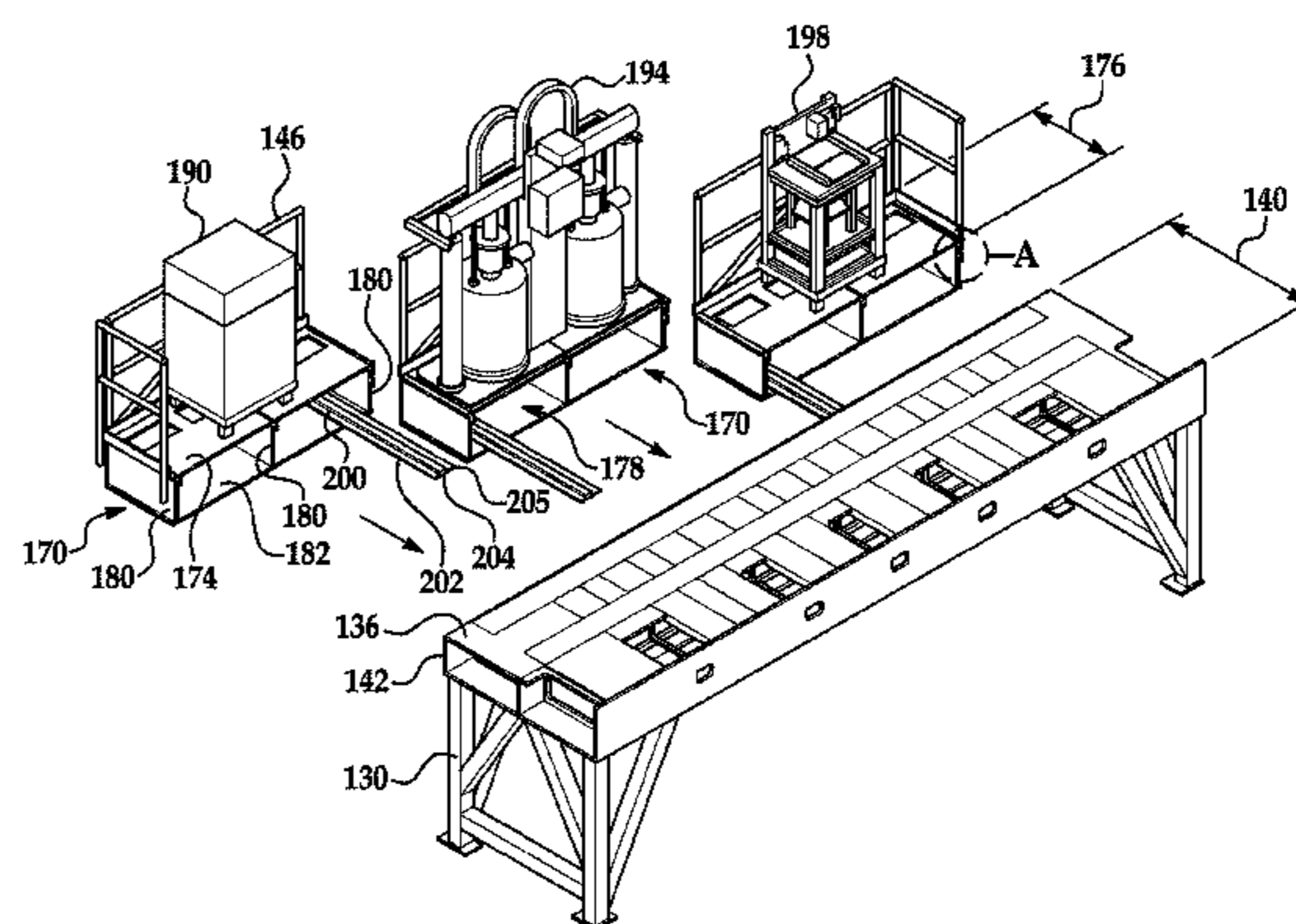
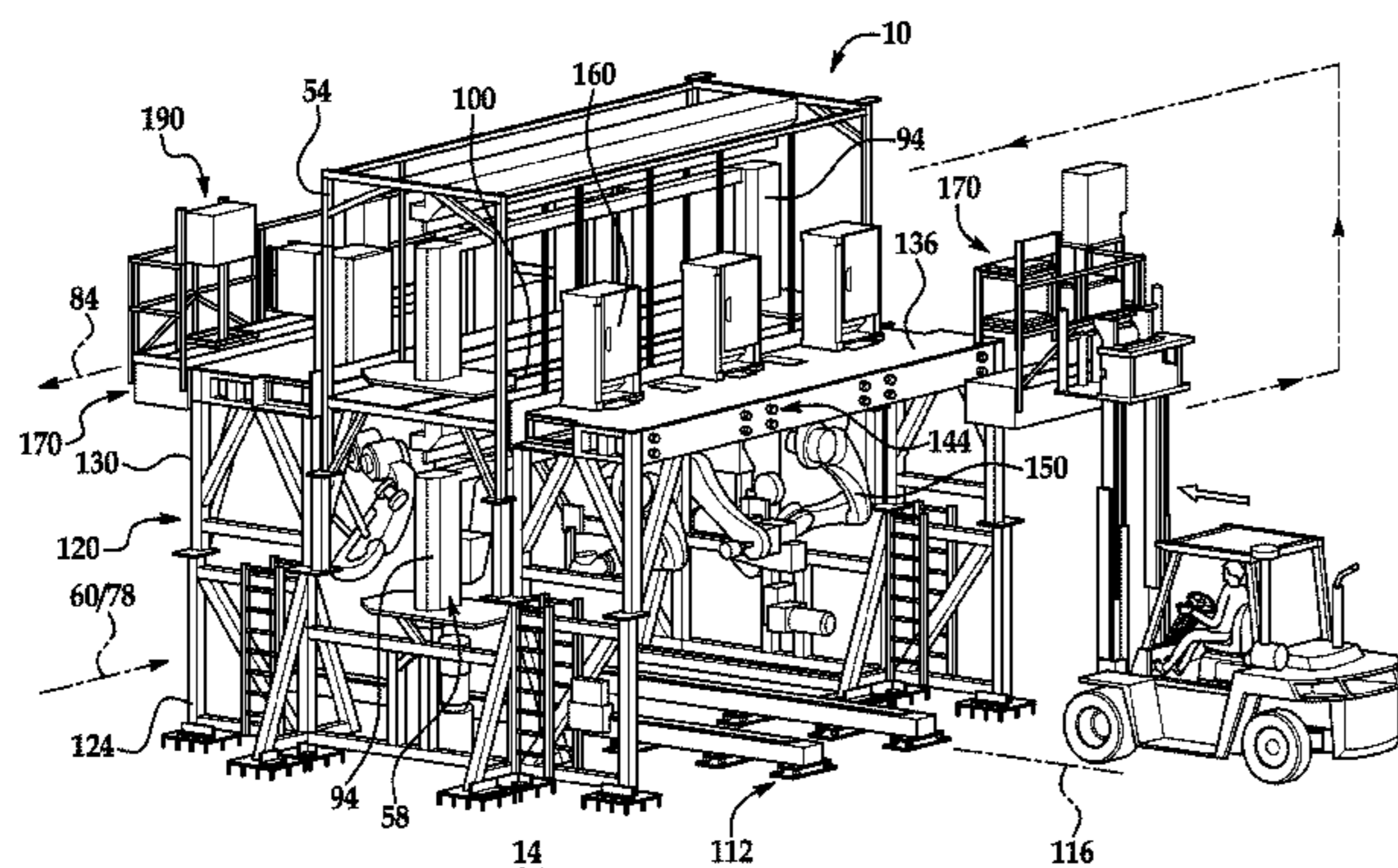
FMC; Automated Fork lifts and Material Handling Lifts—Forked Automated Guided Vehicles; <http://www.fmcsgrvs.com/content/products/forked.sub.—vehicles.htm>; p. 1.
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(57) **ABSTRACT**

A modular vehicle assembly system and methods for increased flexibility and adaptability of a high volume assembly facility which builds several vehicle models. In one example, the invention includes modular assembly equipment (AE) support pallets which are shipped to vendors for installation of selected AE equipment devices that are specific to a predetermined assembly operation and then validation tested prior to shipment. The modular AE pallets and AE devices are quickly installed and easily removable for maintenance or replacement. In other examples, modular AE support platforms and safety fencing are used to support ground level assembly operation and safer working environment.

20 Claims, 16 Drawing Sheets



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B23K 11/30 (2006.01)
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- (52) **U.S. Cl.**
 CPC *B23K 37/047* (2013.01); *B23P 21/004*
 (2013.01); *B62D 65/02* (2013.01); *B23K*
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- (58) **Field of Classification Search**
 CPC *B23P 19/004*; *B23P 19/008*; *B23P 19/007*;
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Y10T 29/5191; *Y10T 29/5196*; *Y10T*
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29/53435; *Y10T 29/53548*; *B65G 21/00*;
B65G 41/00
 USPC 198/860.1, 860.2
 See application file for complete search history.

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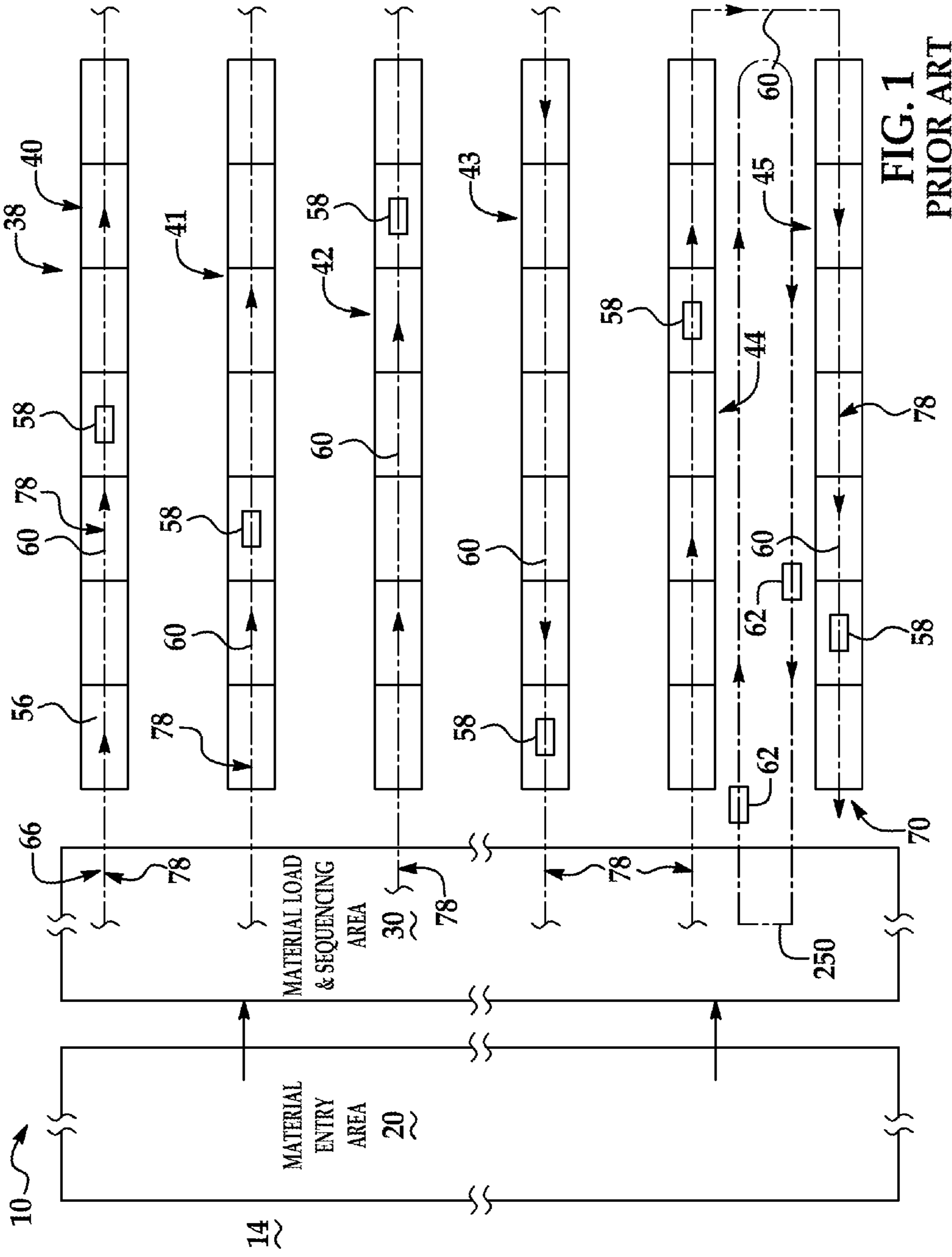
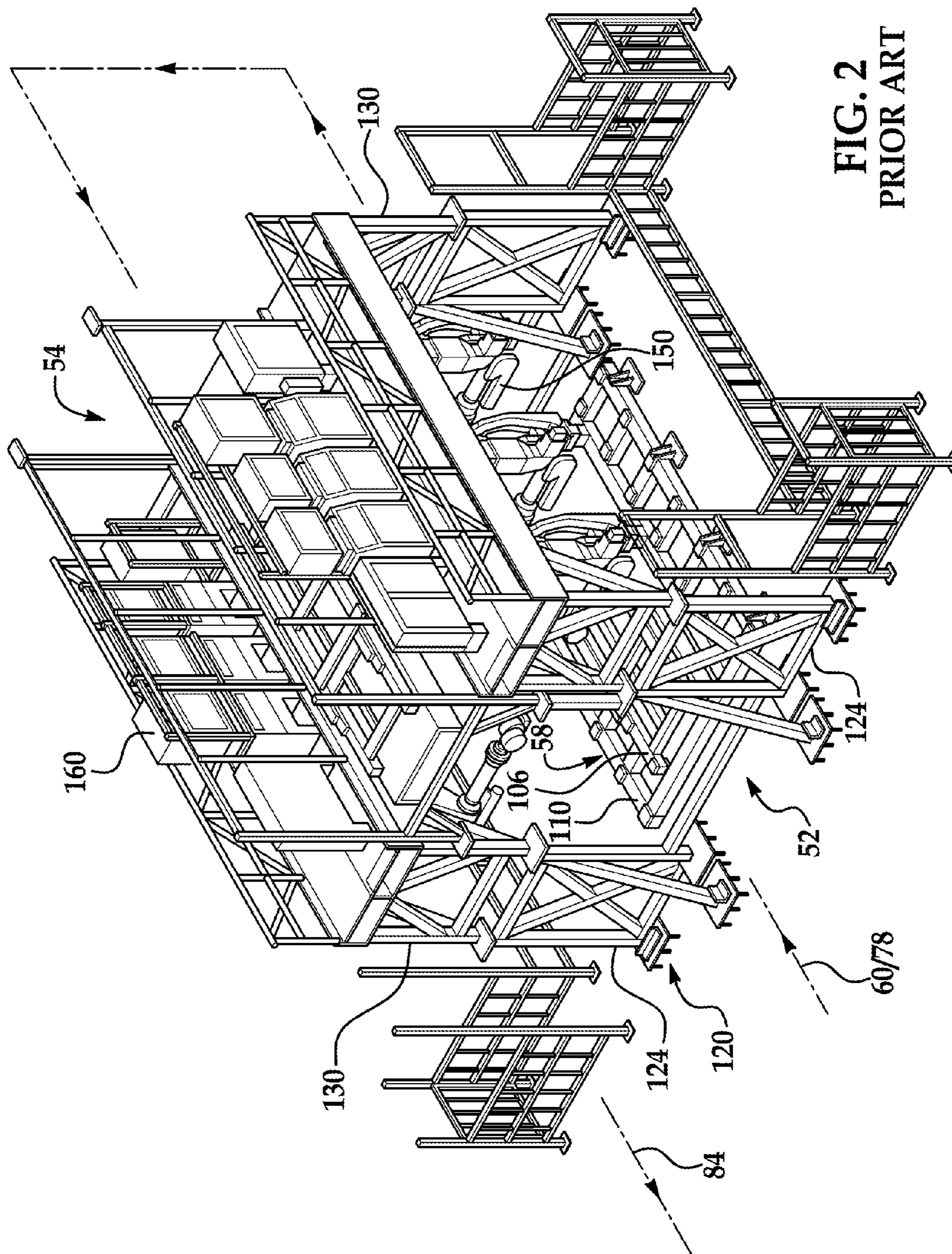


FIG. 1
PRIOR ART



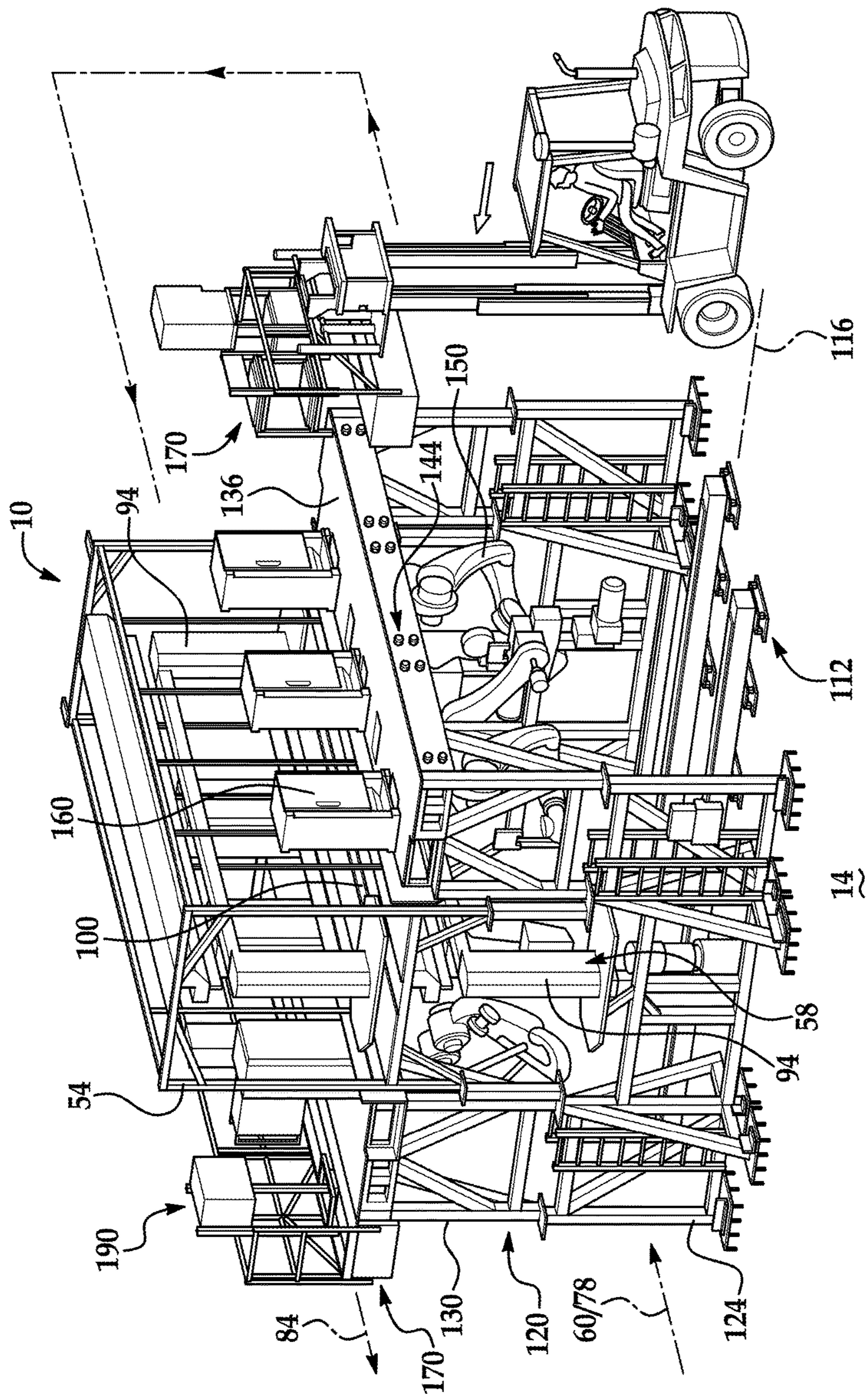
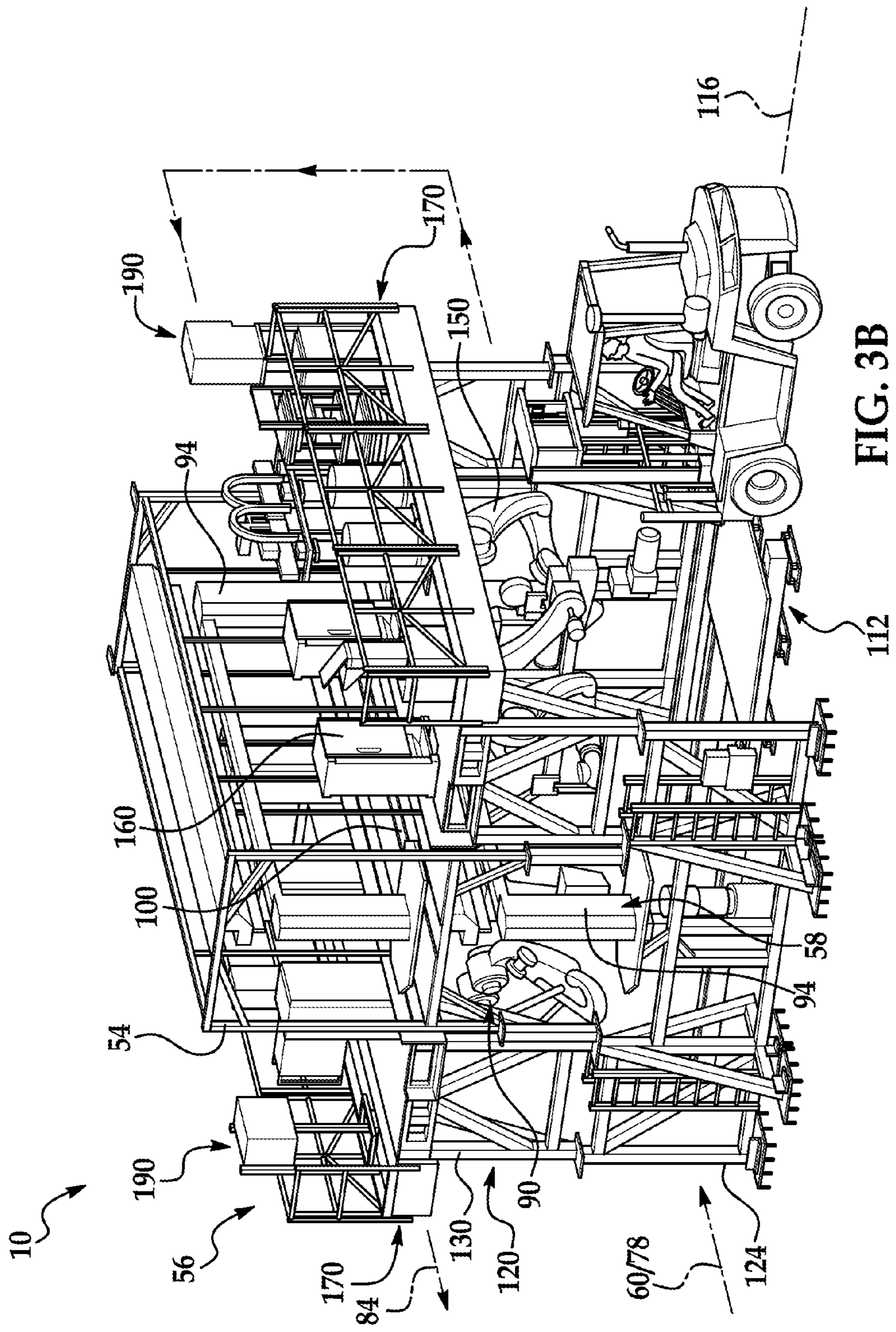


FIG. 3A



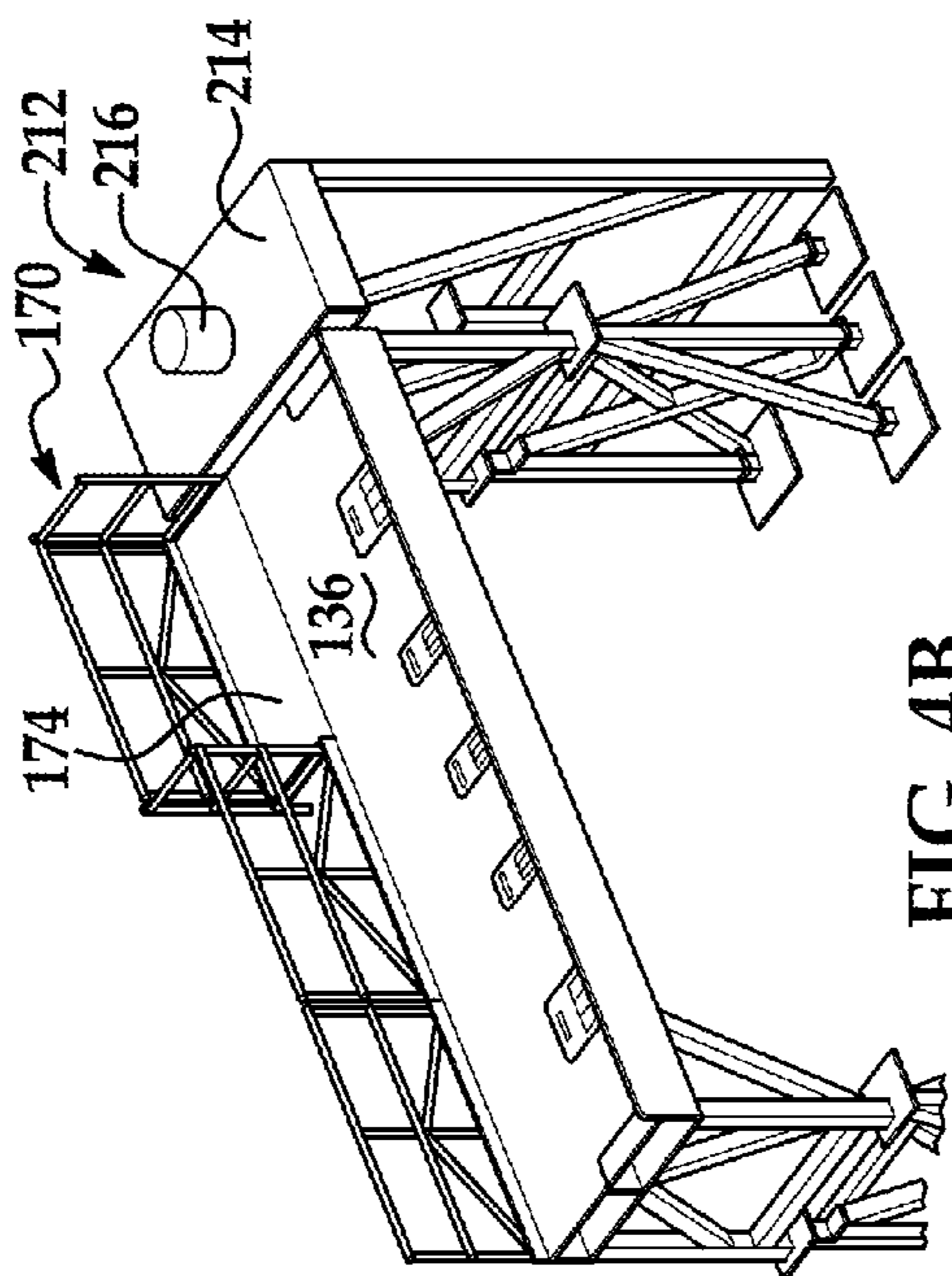


FIG. 4B

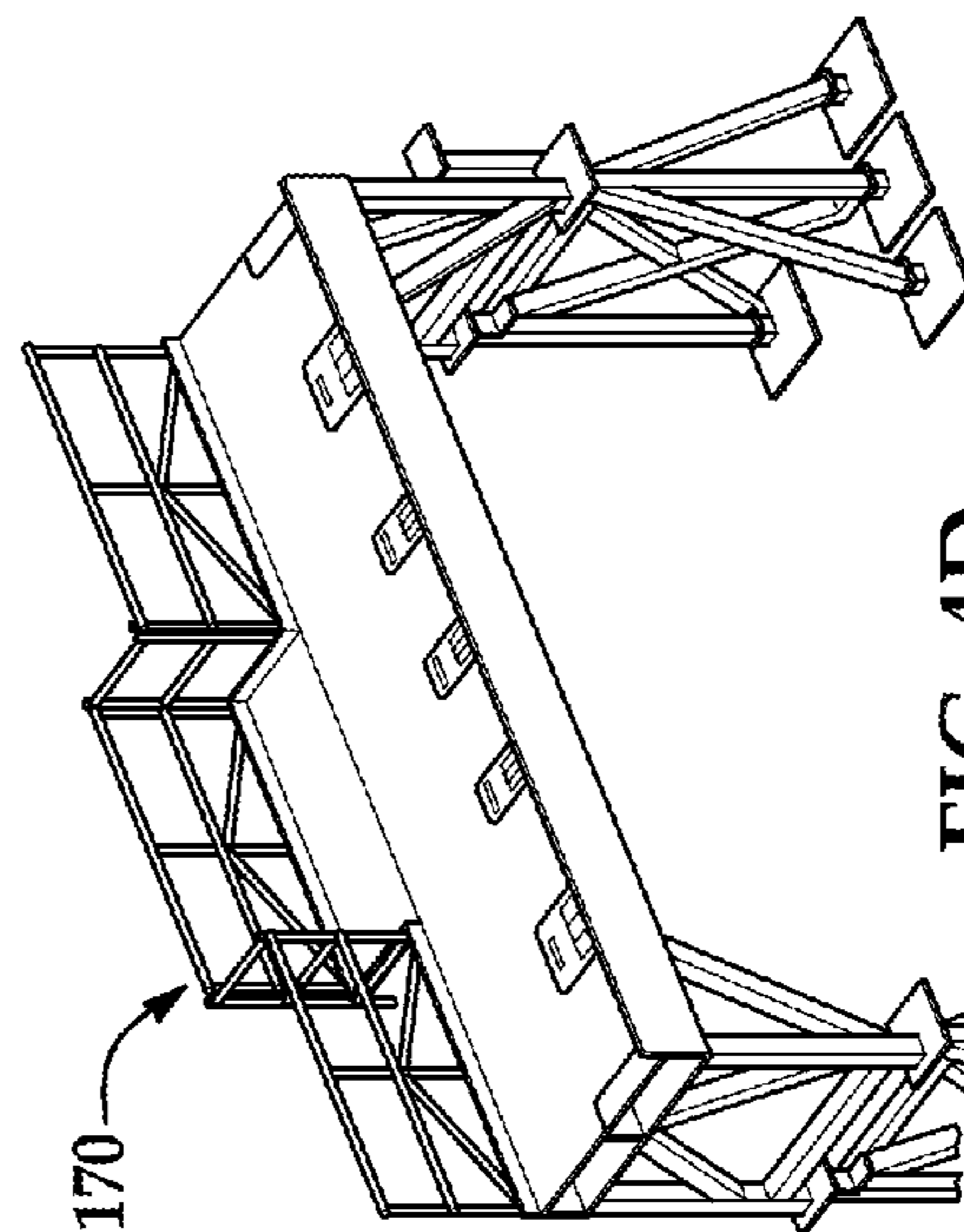


FIG. 4D

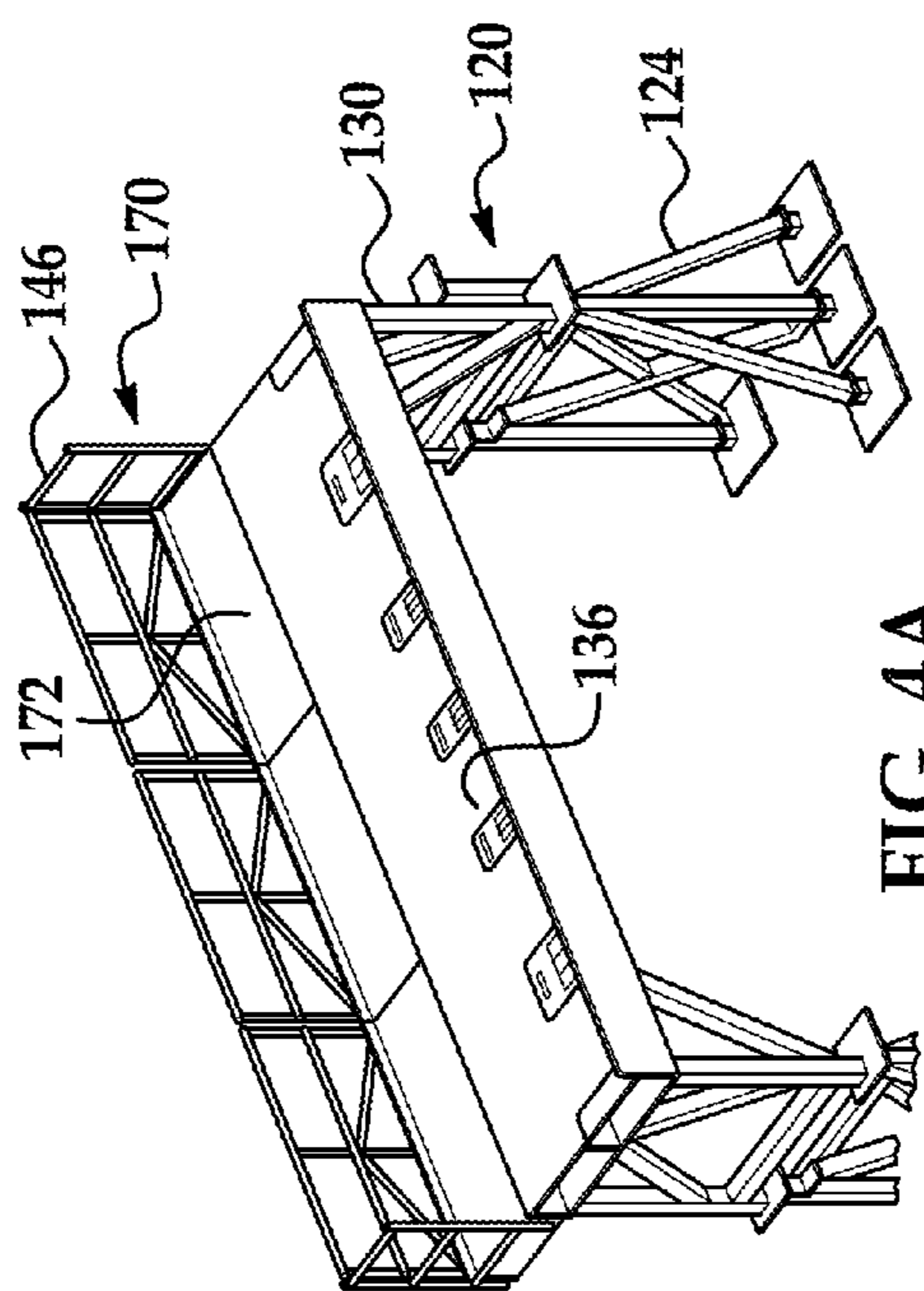


FIG. 4A

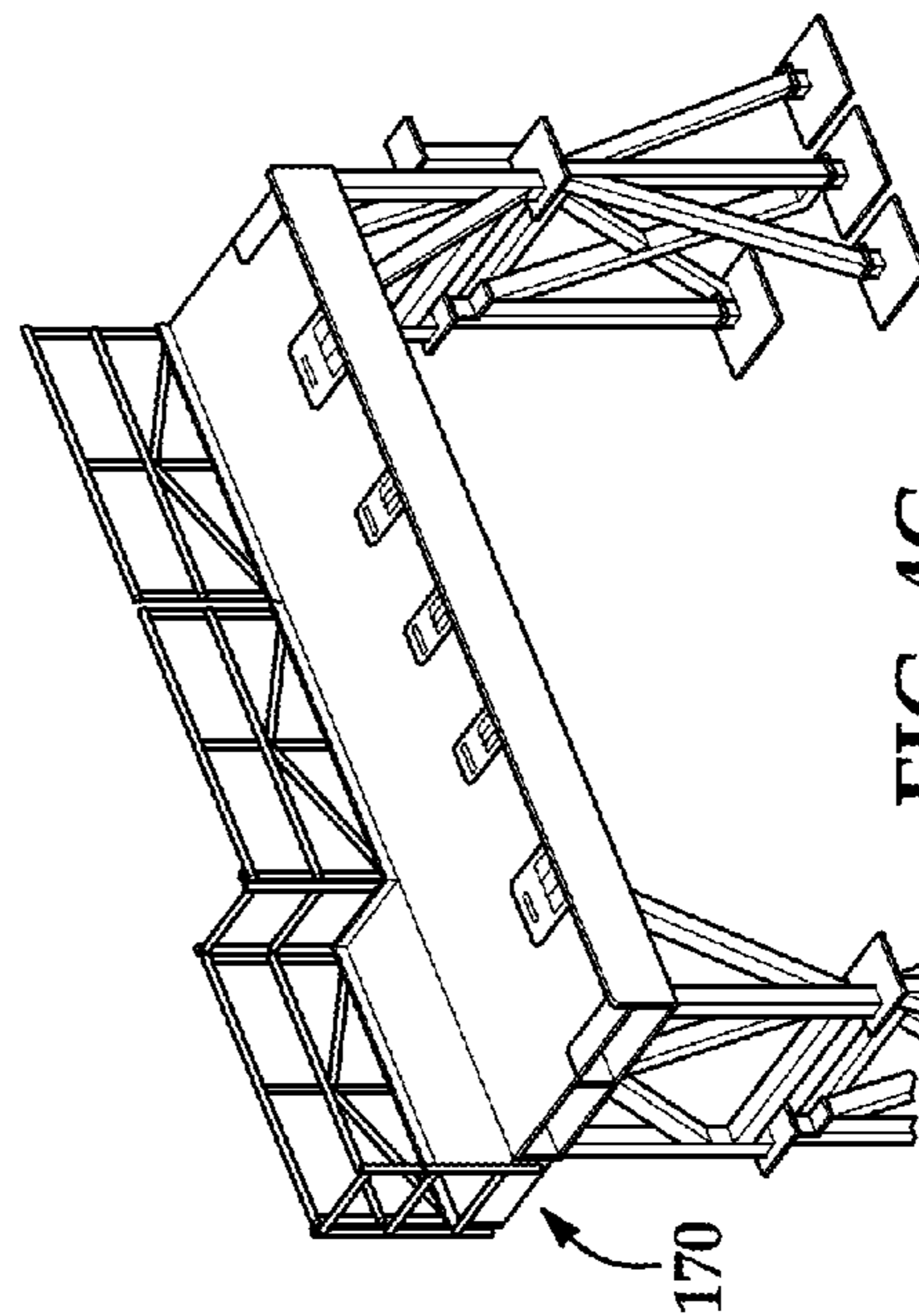
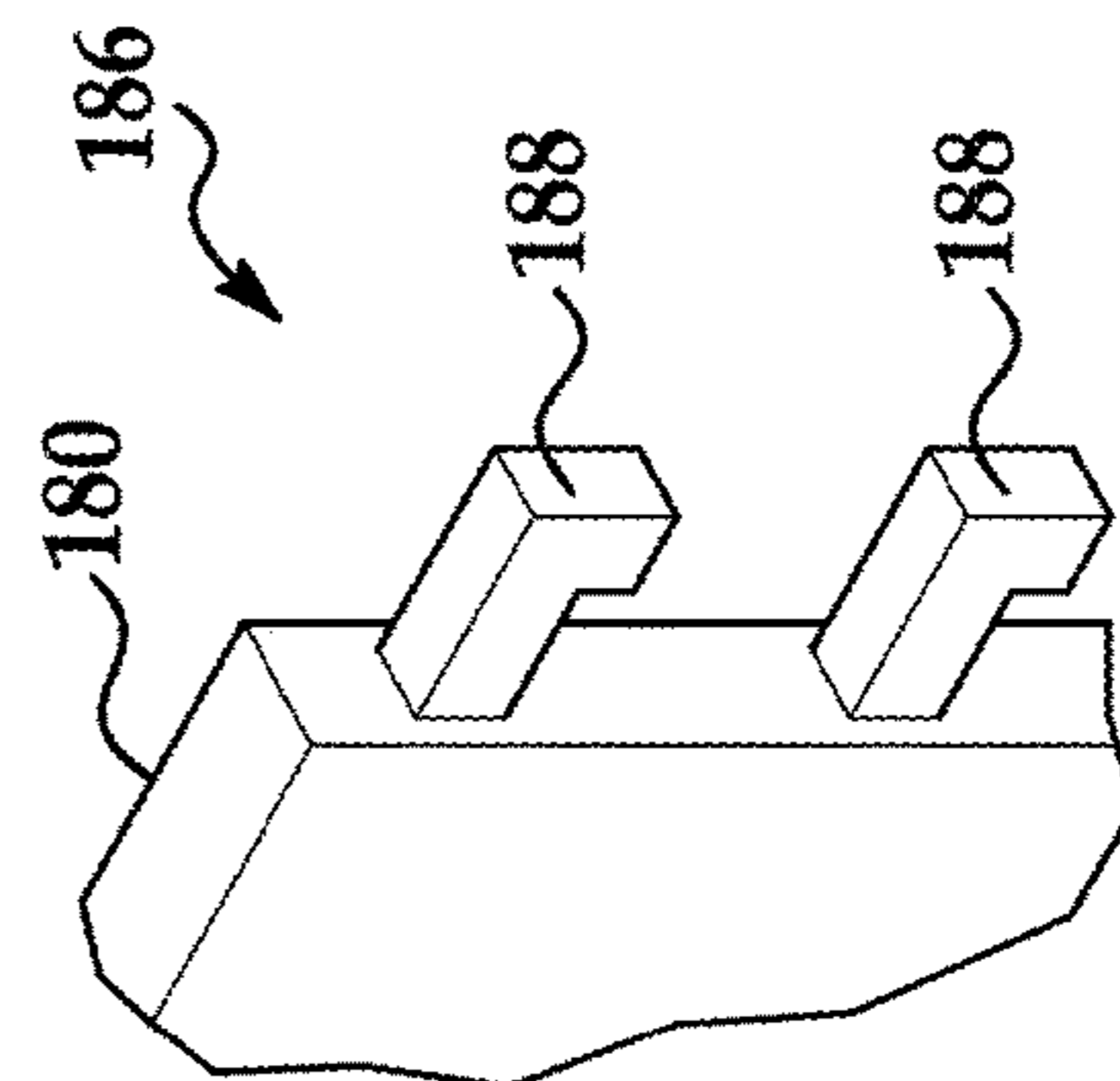
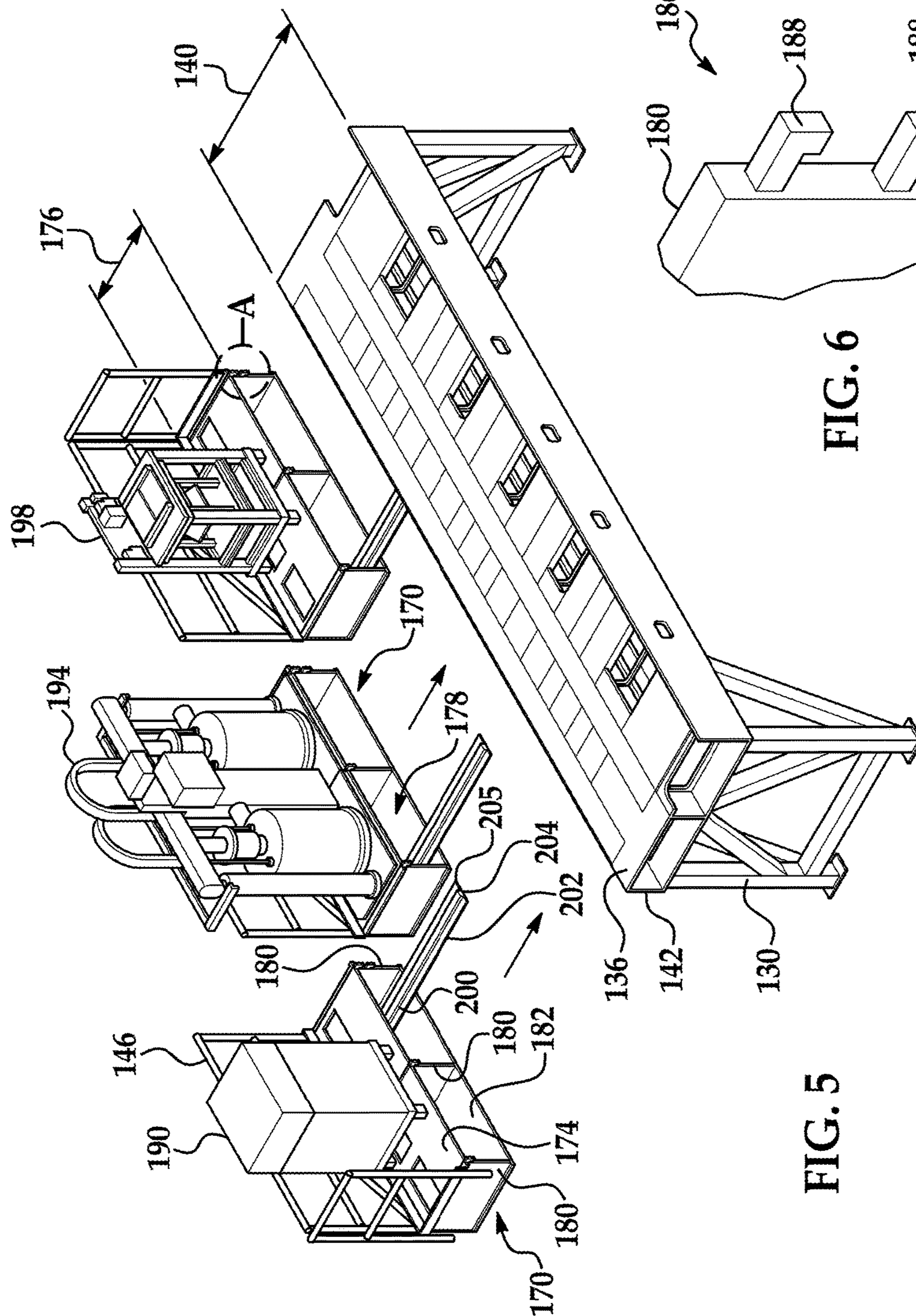


FIG. 4C



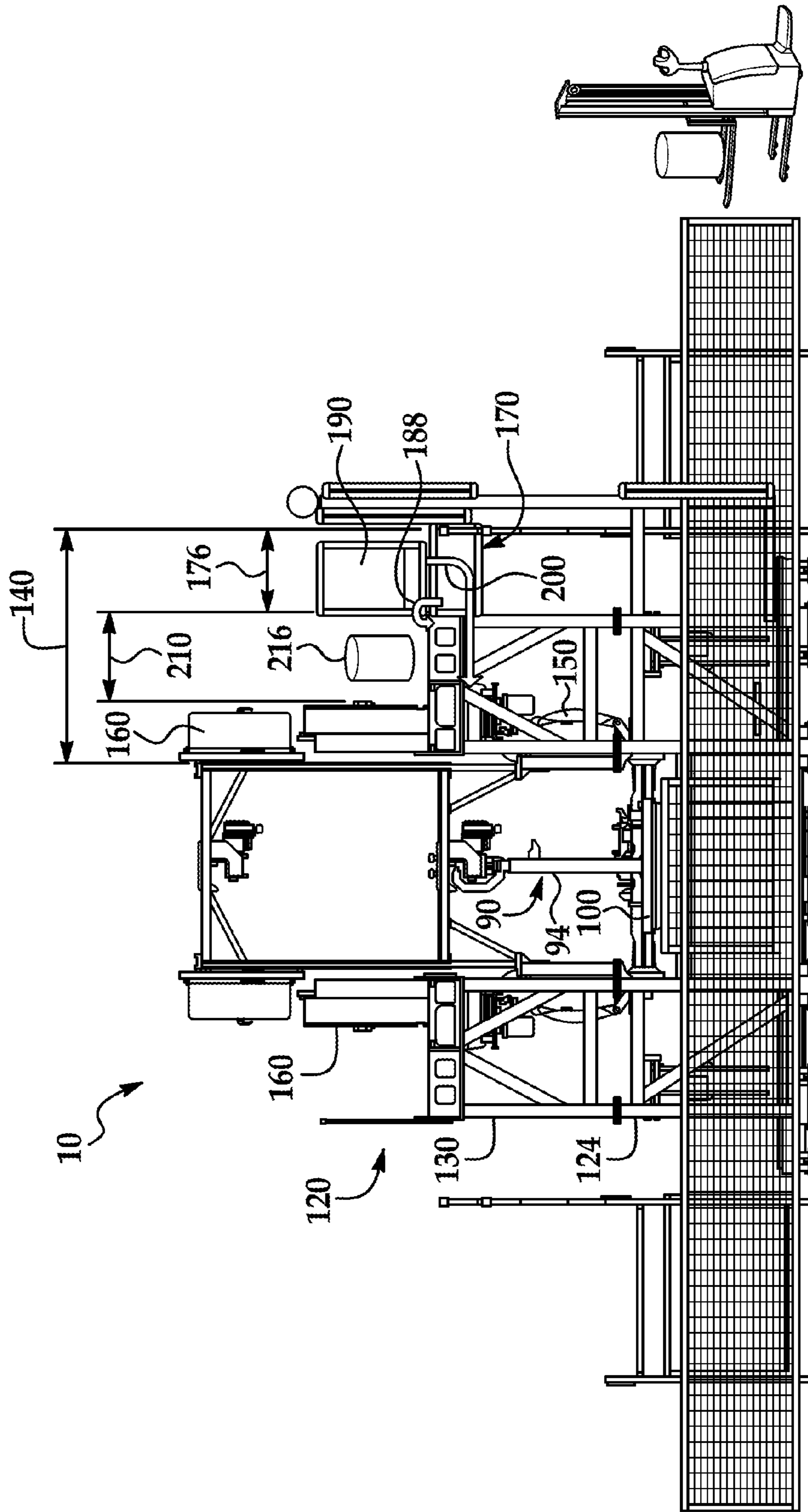


FIG. 7

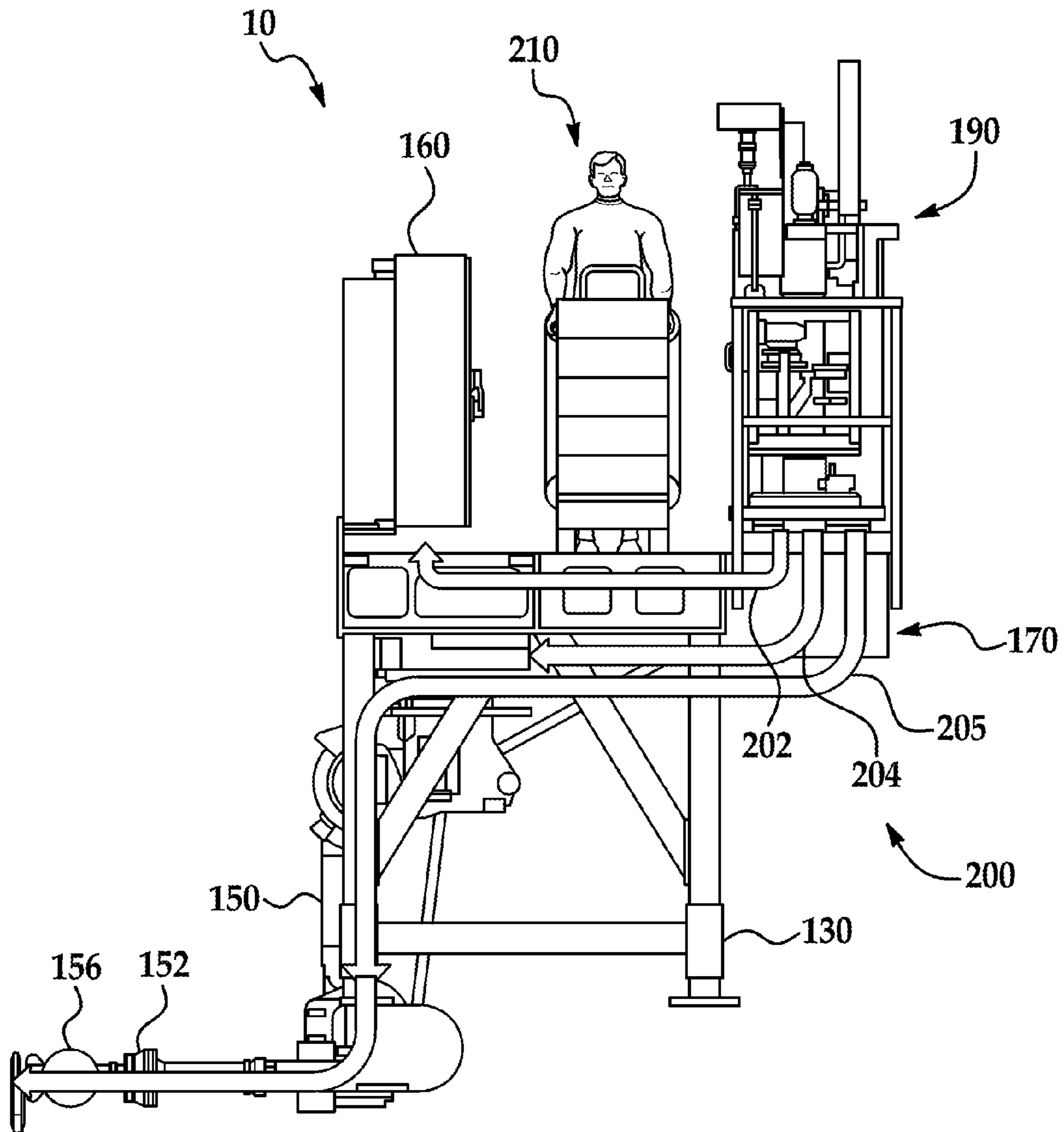


FIG. 8

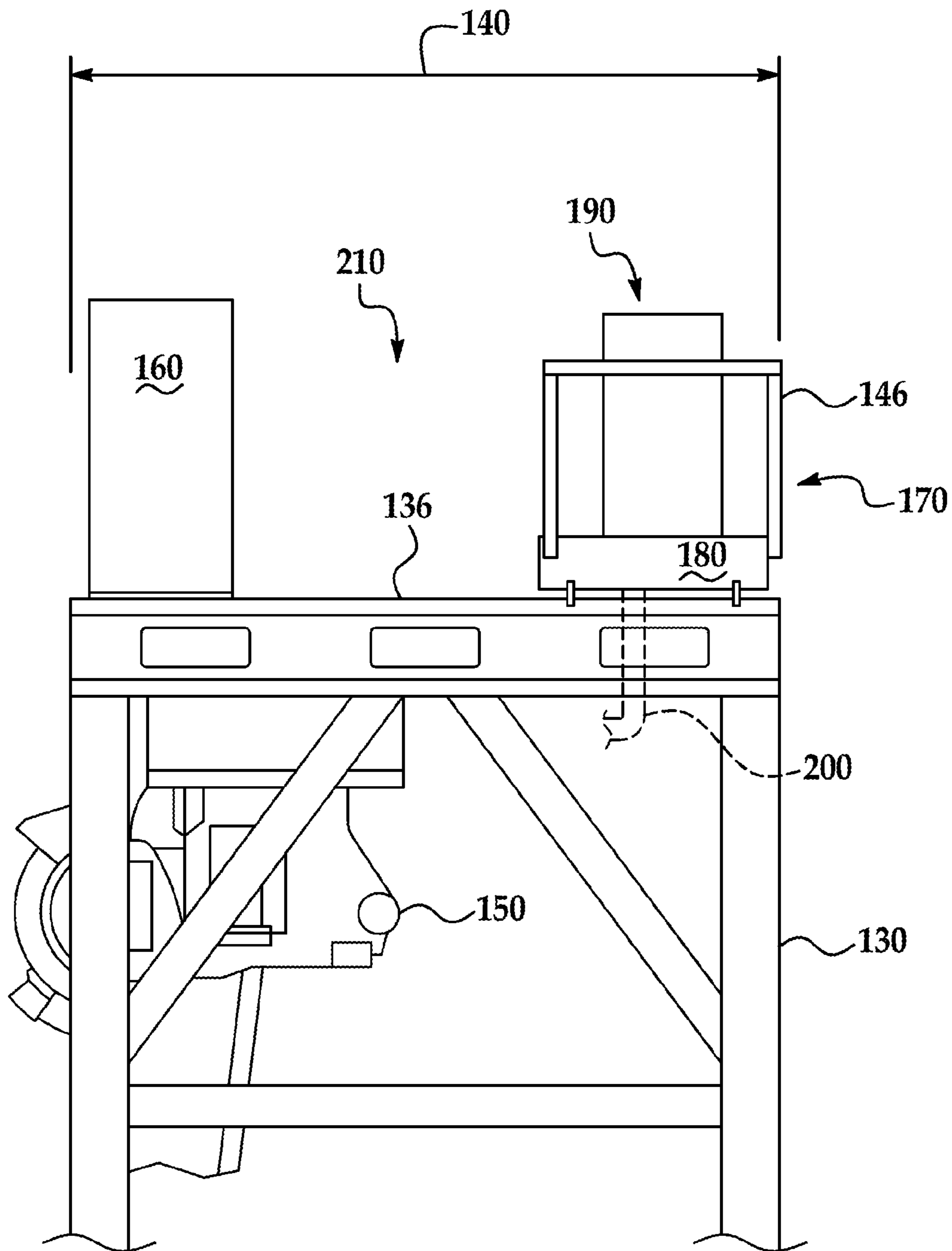


FIG. 9

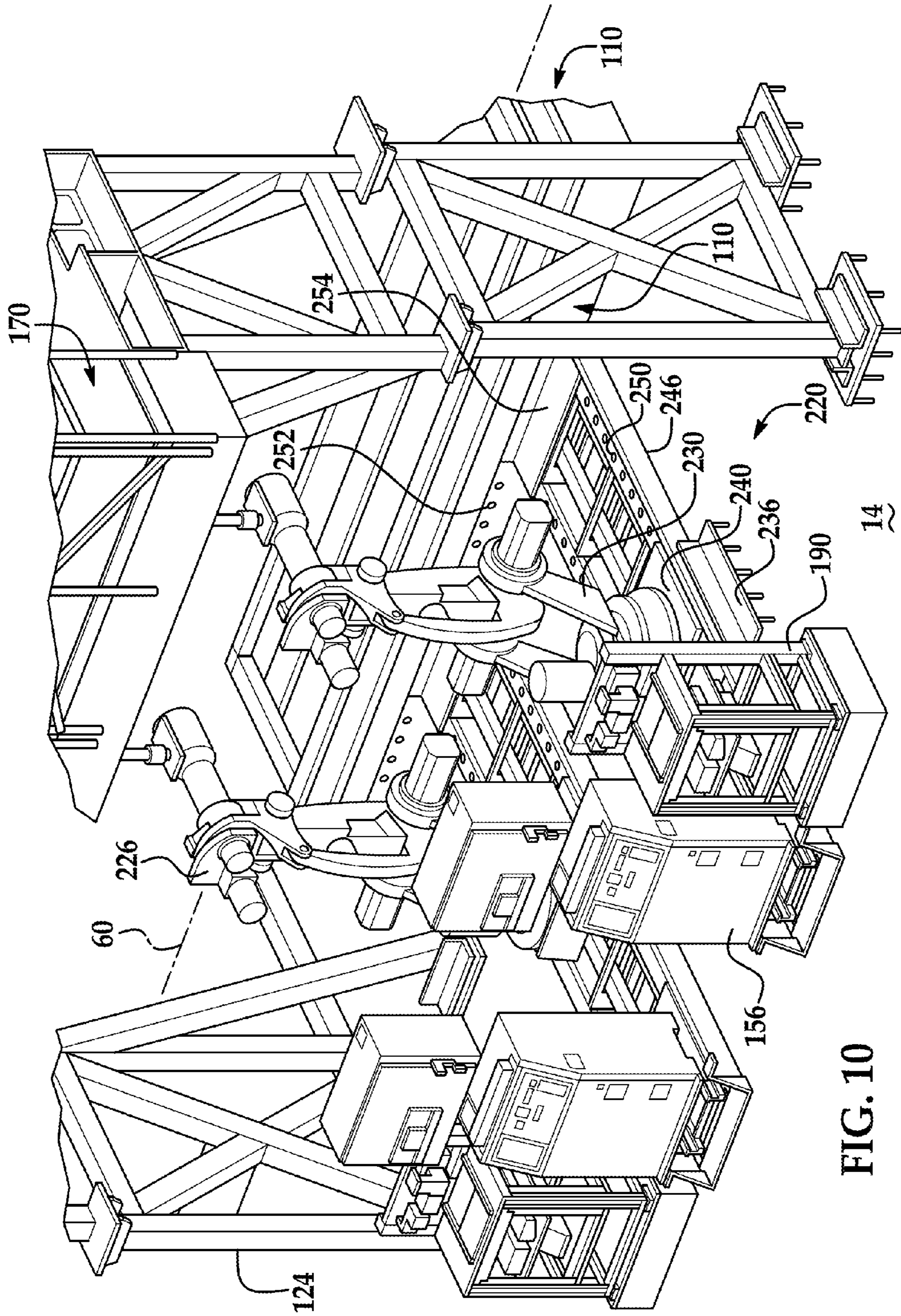
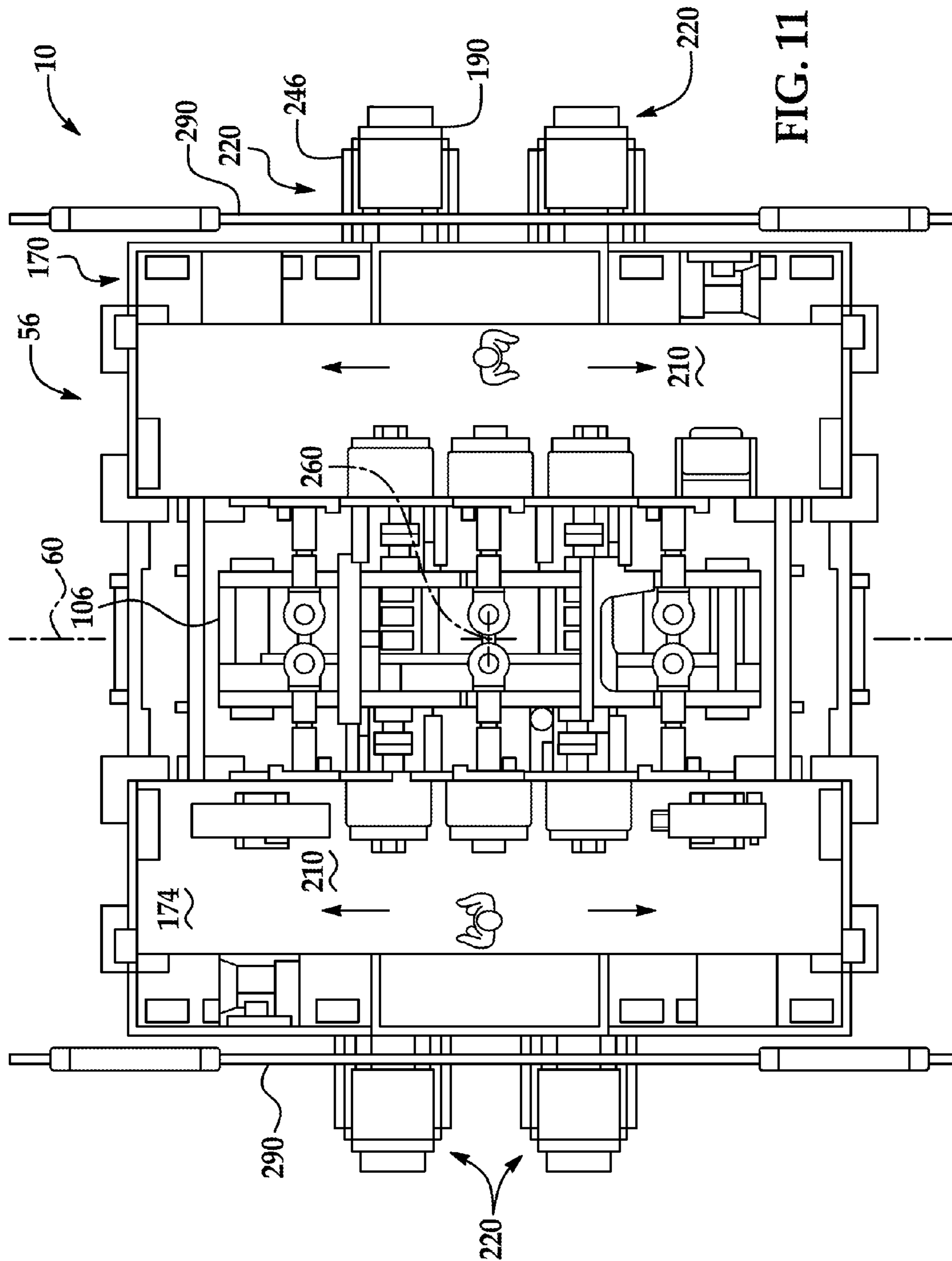


FIG. 10



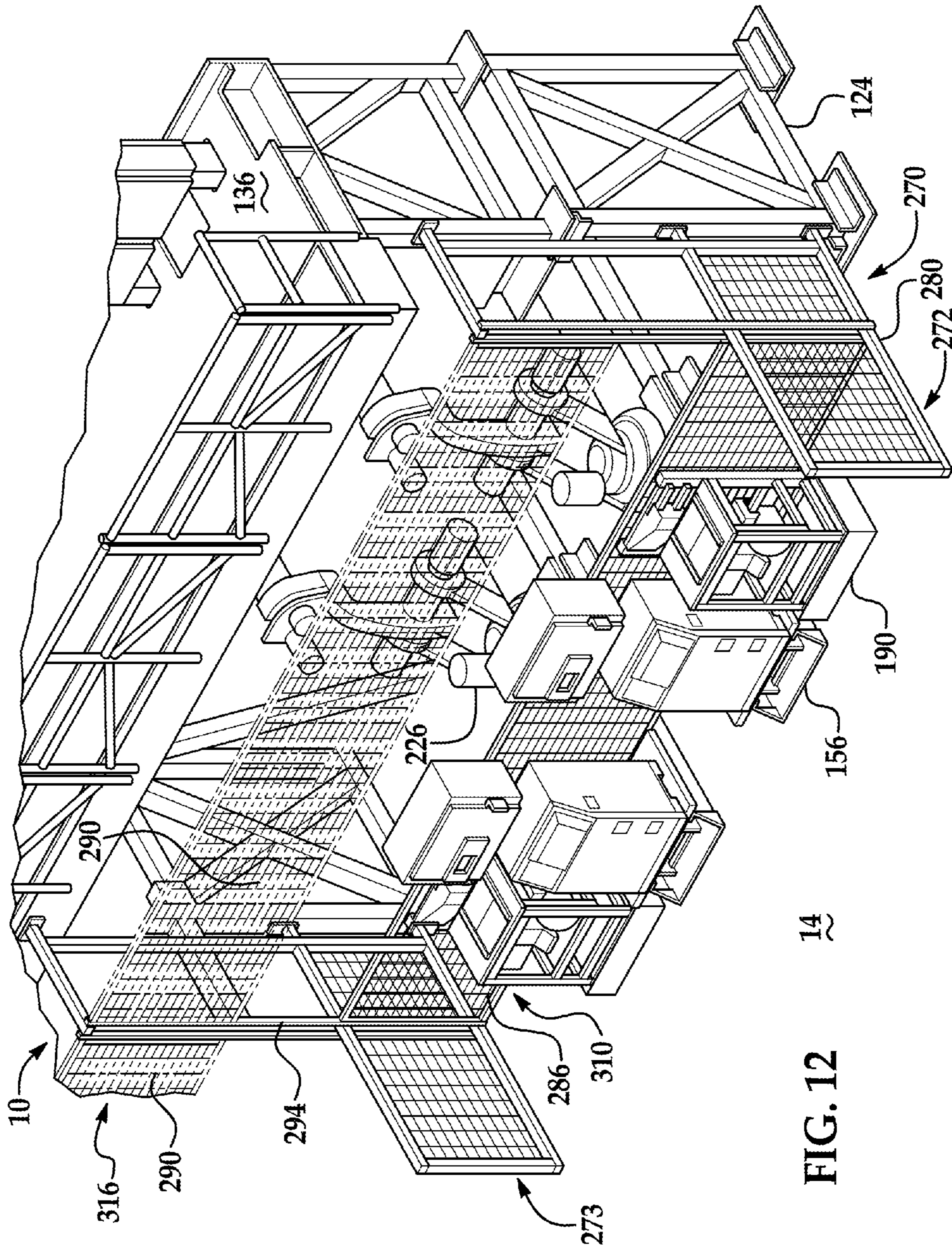


FIG. 12

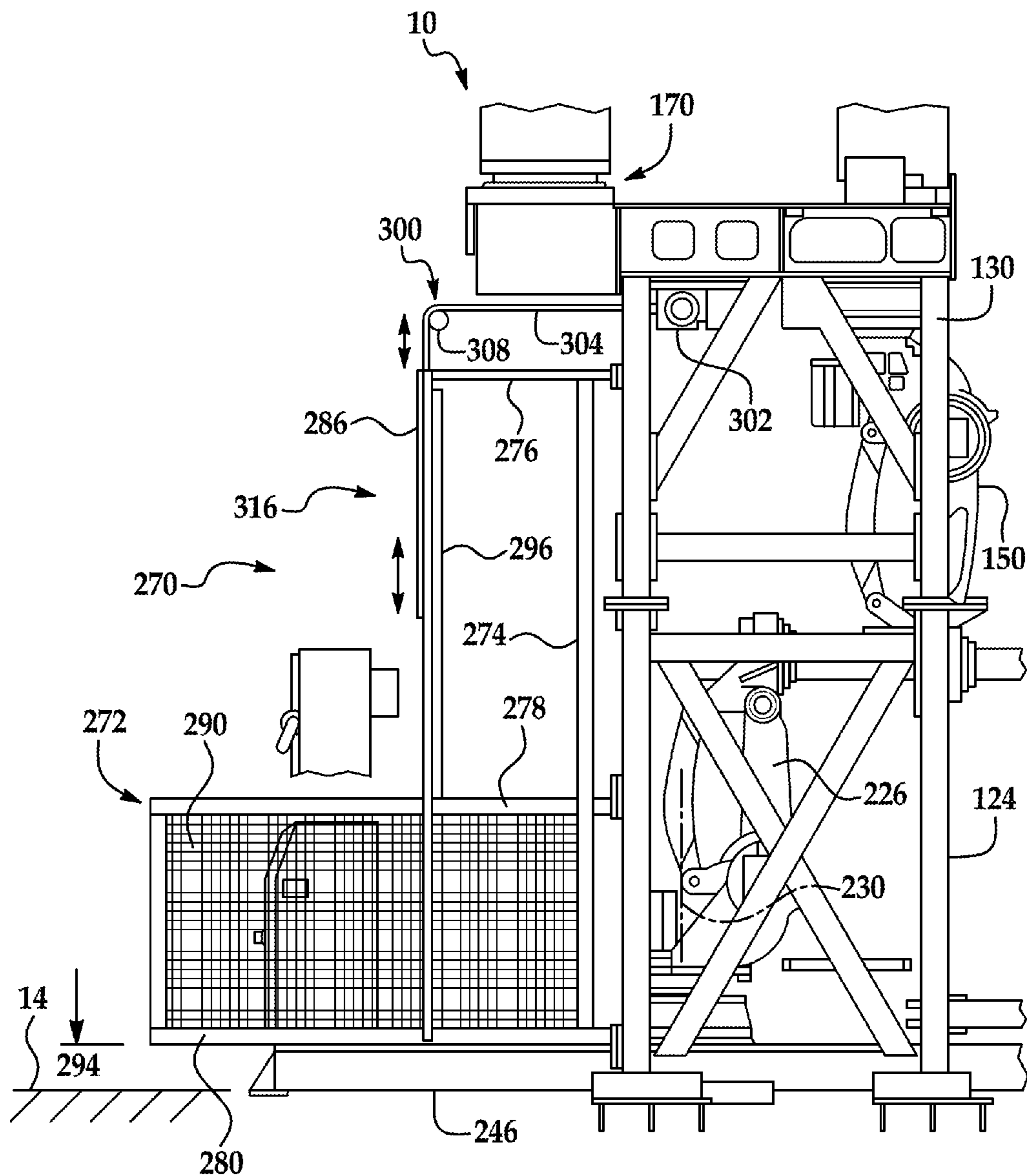


FIG. 13

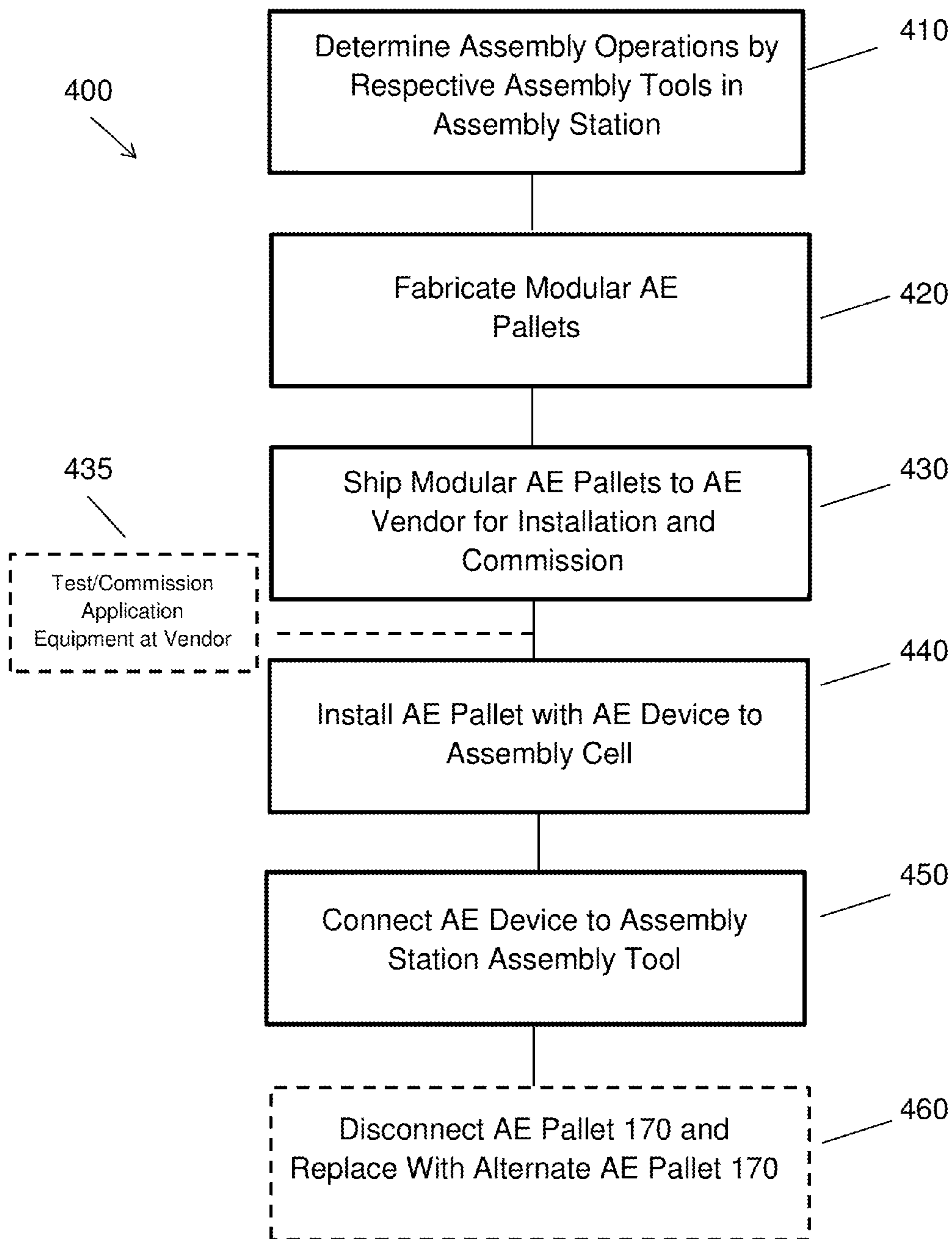


FIG. 14

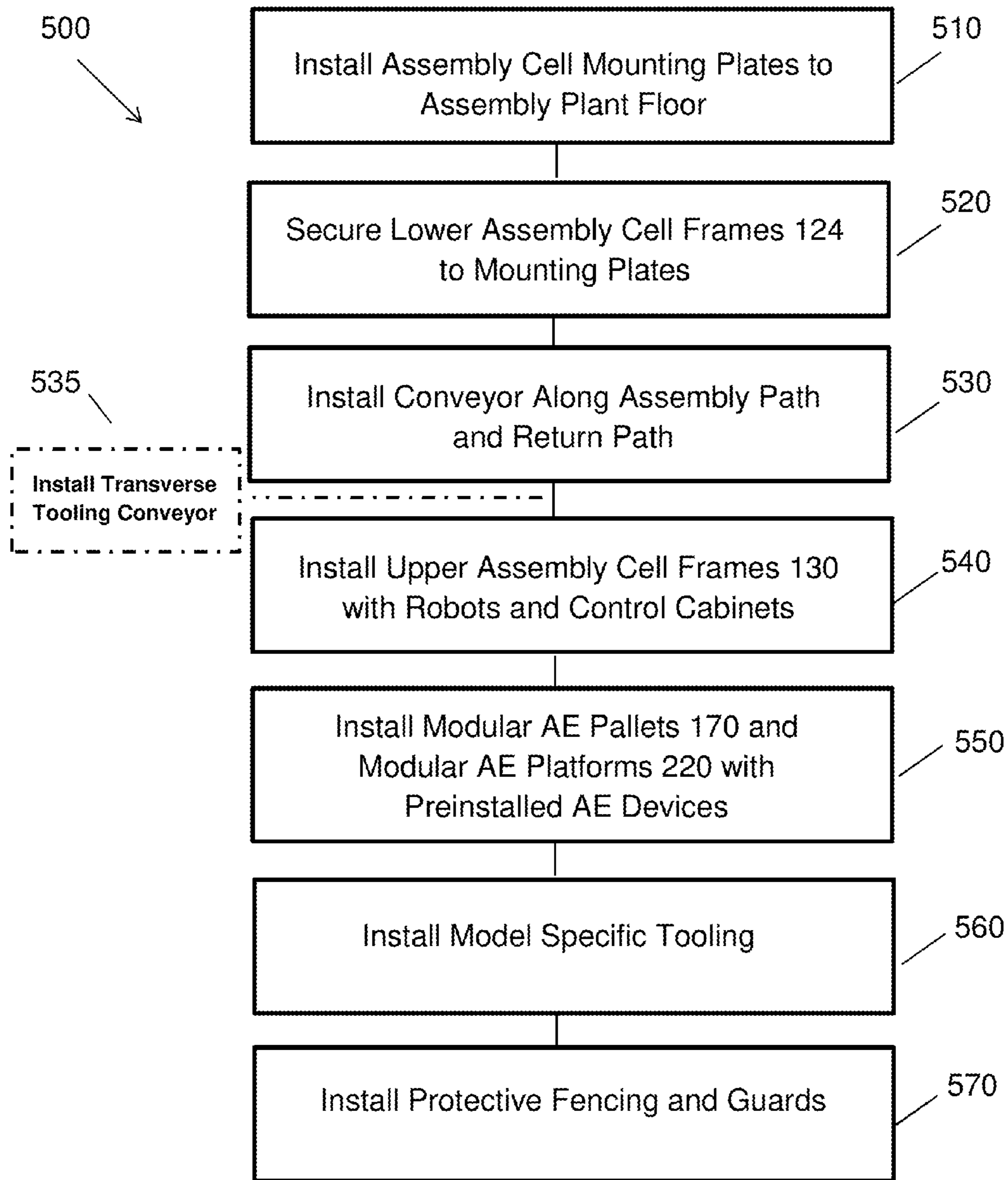


FIG.15

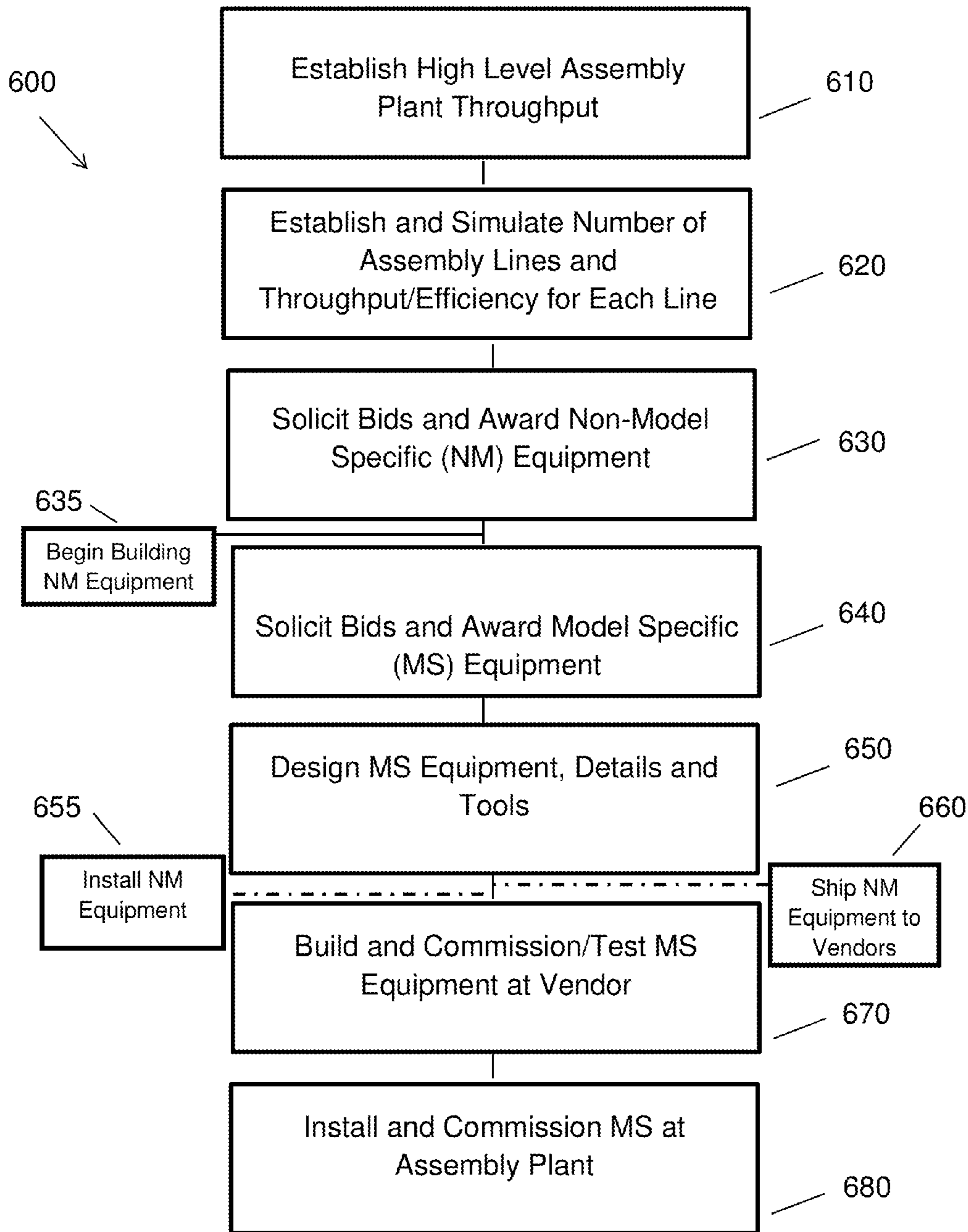


FIG. 16

MODULAR VEHICLE ASSEMBLY SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority benefit to U.S. Provisional Patent Application No. 62/091,687 filed Dec. 15, 2014 the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

The invention generally pertains to the field of product and vehicle assembly.

BACKGROUND

Traditional high volume manufacture and assembly of products, machines and vehicles has occurred in large assembly plants. These assembly plants have included multiple assembly lines where components are gathered, assembled and connected together. In the manufacture and assembly of vehicular bodies, the bodies typically include a skeleton of sheet metal components that are welded together through resistance spot welding, seam welding and brazing techniques to form what are commonly called “body-in-white” (BIW) structures.

With the growing need to efficiently build vehicles and accommodate varying consumer demand, assembly plants have strived to employ flexible build processes so that different vehicles and varying vehicle models including alternate vehicle bodies, can be built along the same assembly lines. The ability to quickly change over from building one type of body to another causes significant difficulty for facilities due to the limited amount of space around assembly lines and the time required to change over equipment and components that are specific to one vehicle body.

The design, build, installation and commission (testing or prove-out) of new assembly lines is an enormously time consuming and expensive endeavor for both suppliers and the customer vehicle original equipment manufacturers (OEM’s) ultimately responsible for operation of the assembly facilities and production of the vehicles. Due to increased competition and consumer demand, there is continuous pressure from the OEM’s for lower cost and higher efficiency assembly systems (higher vehicle or unit per hour throughput) and for those assembly systems to be 100 percent operational in a shorter amount of time.

Due to the multiple assembly systems, equipment and components that require sequenced operation to assemble a vehicle (or other product), the design of the overall assembly line traditionally required many stages. For example, the final design of equipment, for example called “Time B” equipment, that relies on a supporting structure, for example called “Time A” equipment, traditionally could not be completed until the design of its Time A supporting structure is complete. Once the various Time A support infrastructure and individual assembly systems were designed, built and installed, a substantial portion of the commission or testing of the Time B equipment traditionally could not occur until all of the Time A support structure and equipment is delivered and installed at the OEM assembly plant. This is further complicated by OEM’s typically awarding portions of the assembly line Time A and Time B equipment to many different suppliers to leverage the respective supplier’s expertise. If a supplier falls behind in the design, build or

installation of Time A equipment, that can delay Time B equipment suppliers causing a cascading of delays through the remainder of the design, build, installation and commission stages. It would be further advantageous to have as many of the assembly equipment and systems be generic or non-model specific. That is, these systems and equipment may be used to build most or all variations of a product or vehicle which may have different models or features. These non-model specific systems and equipment (Time A) could then be fabricated, installed and commissioned even when final decisions about the product to be produced have not been made (which affect the Time B non-generic or model-specific assembly equipment and systems).

It has further been time consuming and costly for vehicle OEM’s to change over an assembly plant or assembly lines to a new vehicle model or different vehicle altogether. Even simple to moderate changes to the assembly line equipment infrastructure can take days or weeks to complete leading to costly production downtime.

Prior assembly systems have employed specific assembly plant layouts to decrease the plant floor space required and increase efficiency in operations and vehicle throughput. For example, the ComauFlex system, produced by the same assignee of the present invention, has been widely employed by OEM’s the details of which can be reviewed in U.S. Pat. No. 8,201,723 the entire contents of which is incorporated herein by reference and briefly discussed below. Details of variations of the ComauFlex assembly plant layout systems can further be found in U.S. Pat. Nos. 8,869,370; 8,713,780 and U.S. Patent Application Publication 2012/0304446 all assigned to assignee of the present invention and all incorporated herein by reference. These prior systems further reduced the need to store to-be-installed components and subassemblies next to the assembly line and specific assembly stations or cells which cluttered the assembly floor and complicated logistics.

Prior assembly systems have employed some modular vehicle assembly subsystems which provided advantages in new installations and accommodating batch and random vehicle builds where different vehicle models or types of vehicles could be built along the same assembly line with reduced changeover time. Prior assembly subsystems have employed modular robotic assembly stations or cells which could be placed end-to-end to accommodate a specified assembly line or series of operations. For example, each assembly station or cell included a modular, precision-manufactured to close tolerances scaffold frame structure and could be selectively equipped with the necessary number of industrial, multi-axis robots and end effectors for a specified assembly operation. Details can be found in the above-referenced U.S. Pat. Nos. 8,201,723; 8,869,370; 8,713,780 and U.S. Patent Application Publication 2012/0304446 all incorporated herein by reference.

Despite the numerous efficiencies and advantages prior assembly systems provide, many of the above-referenced complexities and disadvantages continue in the design, build, assembly and commission of these equipment and process subsystems, and the assembly system as a whole, in the field. For example, peripheral equipment used in vehicle assembly, for example liquid sealant dispensing devices and fastener feeders, required to support the robot assembly operations at a particular assembly station are traditionally placed on the plant floor and separate conveying systems required to transfer the sealant or fasteners to the robots positioned in the assembly cell for use. As another example, where floor-mounted robots are needed in an assembly cell, much time and effort is traditionally needed to precisely

locate and mount the robots in positional relation to the other robots and equipment in the assembly cell. As another example, safety fencing used around an assembly line or cell cannot be designed and tested until most of the assembly cell equipment is designed and installed at the assembly facility.

BRIEF SUMMARY

Examples of the present invention include a modular vehicle assembly line having a plurality of assembly cells having modular systems and equipment which improves on the above complexities and disadvantages in prior assembly systems and methods.

In one example of the invention, a modular application equipment (AE) support pallet device is selectively used to elevationally support and secure application equipment, for example liquid sealant storage tanks and distribution pumps, above the assembly line and assembly tools, for example robots. The modular pallet is selectively connected to the assembly cell frame directly adjacent to, or in close proximity to, the robot (or other assembly tools or equipment) using the specific application equipment and further provides a simple logistical path to convey the consumable material, sealant, fasteners etc. directly into the assembly cell and the robot for application. In an example of a method of the invention, the modular pallet device can be pre-constructed and shipped to the application equipment supplier wherein the application equipment can be mounted and tested at the supplier prior to delivery and installation at the assembly plant. Power, data and material conveying cables and hoses for the mounted peripheral equipment can simply be connected to coordinating equipment at a system integrator's facility or directly at assembly plant for a "plug and play" device enabling efficient installation, connection and commission/testing at the assembly plant.

In another example of an aspect the invention, a modular assembly tool (AT) platform or tray is provided to easily locate and secure required assembly tools and associated AE devices to the modular assembly cell infrastructure. In one example, a floor-level modular robot platform is provided. In the example, an industrial programmable robot, control cabinet and associated accessory devices are preinstalled on a modular AT platform or frame which coordinates with the existing modular assembly cell infrastructure. The modular support platform similarly allows the equipment to be pre-tested prior to arrival at the system integrator or assembly plant and provides quick and precise positioning with the existing modular assembly cell infrastructure. The simple, secure and precise positioning of the robot relative to the platform, and the platform relative to the assembly cell or station, provides immediate, predictable and highly repeatable location of the robot to the other assembly cell equipment greatly reducing the time and effort to positionally orient, program, and calibrate the robot over traditional devices and methods. The exemplary modular AT platform further provides secure and predictable positioning of AE devices relative to the robot, for example weld tip dressers for spot welding gun end effectors connected to the robots, further adding to plug and play advantages on installation at the assembly plant as described above.

On the need for significant maintenance of the application equipment, or a model changeover at the assembly plant, the modular AE pallets and AT platforms having non-model specific or model-specific AE devices and assembly tools are simply "unplugged" from the non-model specific assembly structures and replaced with the new, refurbished and/or AE

devices or assembly tool equipment for the new vehicle model that has been tested/commissioned prior to arrival at the assembly facility or line.

In another example of an aspect of the invention a modular guard fence is used with one or more aspects of the modular assembly station and modular inventive aspects noted above and discussed below. In an example, the guard fence includes a frame that is cantilevered from the assembly frame and, may, but in a preferred aspect, does not require connection to an assembly plant floor which was expensive and time consuming in conventional safety fences and guards. The exemplary fence includes an upper position and a lower position allowing selective access to assembly tools in the assembly station. In one example, a front panel is positioned between the assembly tools and control cabinets and AE devices of an AT platform. This prevents unauthorized access to the assembly tools while allowing access to the control cabinets and selected AE devices while the assembly tools are in operation.

In another example of an aspect of the invention a method of establishing and purchasing a vehicle (or other product) assembly line is presented. In the example, an assembly plant throughput is established and the number of individual assembly lines forming the complete assembly line is determined. The throughput for each assembly line is calculated to meet the overall throughput target. The required assembly line equipment and services are divided up into non-model specific infrastructure equipment and services that are non-vehicle model specific and vehicle model-specific systems.

The non-model specific systems may include the modular frames, conveyors and AE pallets and AT platforms. The non-model specific equipment is singly sourced to a supplier or a minimal number of suppliers. The vehicle model-specific assembly equipment is competitively bid, preferably on an individual assembly line by assembly line basis, the supplier awarded the individual line or lines being responsible for meeting the individual line throughput specification.

The method provides at least the advantages of simultaneous and parallel design activities for non-model specific and model specific equipment, immediate design release of the modular non-model specific technical details of the assembly lines, increased commission of the equipment at the suppliers and rapid installation and final commission at the assembly plant through connection of the modular assembly line components and application equipment mounted thereto. This results in compressed timing to design and install an assembly facility at lower cost and overall lowered business risk which is more evenly shared between the OEM and suppliers awarded portions of the business.

Other applications and aspects of the present invention will become apparent to those skilled in the art when the following description providing examples of the invention are read in conjunction with the accompanying drawings described below.

BRIEF DESCRIPTION OF THE DRAWINGS

The description herein makes reference to the accompanying drawings wherein like reference numerals refer to like parts throughout the several views, and wherein:

FIG. 1 is a schematic of an example of a prior art vehicle assembly plant layout and assembly lines;

FIG. 2 is a perspective view schematic of one example of a prior art vehicle assembly station having a pallet-style vehicle conveyor;

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FIG. 3A is a perspective view schematic of an example of a modular vehicle assembly station of the present invention with an exemplary overhead-style conveyor and peripheral support device being installed;

FIG. 3B is an alternate perspective view schematic of the example shown in FIG. 3A with several modular pallet devices installed on both sides of the assembly station;

FIGS. 4 A-D are alternate examples of configurations for one example of the modular application equipment pallet devices;

FIG. 5 is a perspective view schematic of an example of the modular application equipment pallet device and exemplary application equipment devices mounted thereon;

FIG. 6 is an enlarged perspective view schematic of the area marked "A" in FIG. 5;

FIG. 7 is a schematic end view of an example of a modular vehicle assembly system station;

FIG. 8 is an alternate and enlarged portion of FIG. 7 showing connection of an exemplary application equipment pallet device;

FIG. 9 is a schematic end view of an alternate example of a modular application equipment pallet device mounted atop of an exemplary frame structure;

FIG. 10 is a perspective view schematic of an example of a modular application equipment platform with a robot connected to a pallet-type conveyor;

FIG. 11 is a plan view schematic of a modular assembly system station including six modular pallet devices and four modular robot platform devices;

FIG. 12 is a perspective view schematic of an example of an assembly station protective fence and fence retraction device;

FIG. 13 is a right side view of the retractable protective fence in FIG. 12;

FIG. 14 is a flow chart of an example of a method for assembling and installing modular application equipment pallets and associated application equipment;

FIG. 15 is a flow chart of an example of a method for assembling or installing a modular vehicle assembly system of the present invention; and

FIG. 16 is a flow chart of an example of a method for purchasing or sourcing vehicle assembly lines using non-model specific and model-specific equipment.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Examples of a modular vehicle assembly system and methods 10 are described below and illustrated in FIGS. 1-16. The exemplary assembly devices and systems are described as useful in high quantity assembling automotive passenger vehicles, but there are other applications for manufacturing and assembling other vehicles and products known by those skilled in the art.

Referring to FIG. 1, a known vehicle assembly line for producing sheet metal skeletons of passenger vehicles known as "body-in-whites" (BIW) is shown on an assembly plant floor 14. In the example, a material entry area 20, a material loading and sequencing or staging area 30, and a plurality of assembly lines 38 (six shown in FIG. 1 and identified as 40-45 as illustrated). Each assembly line 38 includes a vehicle-in-process travel path 60 running down each line 40-45.

In the examples shown, two types of vehicle conveyors are particularly, but not exclusively, useful for transporting the partially completed vehicle body along path 60 and through assembly stations or cells 56. As generally shown in

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FIG. 2, a pallet 106 generally supports a partially completed vehicle body (not shown). The pallet 106 is selectively moved along path 60 on a rail frame 110 having powered rollers to selectively move pallet 106 from assembly cell to assembly cell. An example of a powered pallet system is Comau LLC's VersaPallet brand system. Additional details can be found in U.S. Pat. Nos. 6,564,440 and 6,966,427 which are incorporated herein by reference.

As generally shown in FIGS. 3A and 3B, a useful overhead conveyor is Comau LLC's VersaRoll® brand conveyor including powered rollers along an upper frame rail which engage and move a downward extending carriage along path 60 through the assembly cells 56. Additional details can be found in U.S. Pat. Nos. 6,799,673; 6,564,440 and 6,719,122 which are incorporated herein by reference. A useful system to monitor the position and stop the pallets 106 or overhead carriers 90 at desired positions in the assembly cells is Comau LLC's VersaCoder® system which uses a readable strip connected to the pallet/carriage and a reader. Further details can be found in U.S. Pat. No. 7,108,189 which is incorporated herein by reference.

In either a pallet-style 106 (FIG. 2) or overhead-style 90 (FIGS. 3A and B) vehicle conveyor or carrier, one or more exemplary assembly lines 40-45 may include a lower assembly path 60 and an upper return path 84 as generally shown. In the examples shown, the assembly operations, for example spot welding of sheet metal subassemblies and components, occur along the lower level in assembly cells 56 by programmable industrial, multi-axis robots 150 described further below. The upper return path of travel 84 may be used to return empty pallets or carriers to be restocked with components or fitted with a partially completed vehicle body for additional assembly. Where an upper return path 84 and conveyor is used, a lift (not shown) positioned at the end of an individual assembly line may raise, for example and empty carriage or partially completed vehicle body, from the lower path of travel 60 to the upper path of travel 84. Return of an empty transport carriage may occur if the partially assembled vehicle body is transferred to another carrier for continued assembly along downstream assembly lines.

In an alternate example not shown, depending on the vehicle or product to be built, the above referenced lift (not shown) may be positioned prior to the end of a line 40-45 to raise a partially completed vehicle to the upper path 84. Further, an elevated transverse conveyor (not shown) may move a partially completed vehicle body from an upper path 84 of one line 40-45 to an adjacent line for further build or assembly processes.

As best seen in FIGS. 3A and B, where an overhead conveyor 90 is used, a transverse tooling shuttle or conveyor device 112 may be used. The conveyor 112 allows for different tooling to accommodate different vehicle types to selectively move in and out of the assembly cell 56 along a path 116 that is substantially transverse to assembly path 60. Further details of assembly plant layout, assembly lines, tooling shuttles, component carts and carriers useful with the present invention can be found in U.S. Pat. Nos. 8,201,723; 8,869,370, 8,713,780 and U.S. Patent Application Publication 2012/0304446 all of which are incorporated herein by reference.

Other plant layouts, assembly cells, conveyors and tooling devices and methods known by those skilled in the art may be used with the present invention.

Referring to FIGS. 3A and B, an example of a modular vehicle assembly system 10 is illustrated. In the example, the system includes a pair of scaffold-like frames 120. In the

example, frame **120** includes a lower frame module **124** on each side of the assembly line path of travel **60** as generally shown (one assembly line described hereafter for convenience). In a preferred example, the lower frame module **124** is manufactured and assembled to close dimensional tolerances and rigidly and removably secured to the plant floor **14** through threaded studs connected to mounting plates secured to the floor **14**, typically concrete. In a preferred example, the lower frame modules **124** are precisely spaced laterally from a predetermined and known centerline of the assembly line **60** in the assembly facility. The longitudinal position of the lower frame **124** along the assembly line is also determined through known 3-dimensional coordinate reference positions in the assembly facility. These positions may be defined using a large template or jig using the assembly centerline.

Using the predetermined assembly line center line and proper longitudinal position of the lower frames, in one example, an assembly cell reference center point **260** for the assembly station is determined as best seen in FIG. **12**. In a preferred example, the predetermined reference point **260** provides an accurate and known location in the X, Y and Z dimensional coordinates from which other modular assembly system equipment for example the frames **120** are located from to support precision assembly operations along the assembly line.

In a preferred example, the lower frames **124** include an entrance point, for example the leading frame portion upstream, and an exit point, for example the trailing or furthest portion of frame **120** downstream. The lower frames **124** are precisely positioned longitudinally along path **60** from the known center or reference point **260** to provide a structurally rigid and dimensionally precise foundation for locating upper frames **130**. The precision mounting location of the lower frames **124** along path **60** and precision mounting locations for the robots **150** connected to the frame **120** relative to the known reference point **260** of the assembly cell **56** provide accurate, precise and predictable orientation of the robots **150** for programming the movements of the robots **150** assigned functions in the assembly cell **56**. In a preferred example, the lower frames **124** are non-model specific. That is, lower frames **124** are standard or generic and do not depend on which type of vehicle or vehicle body (or other product) will be built. The exemplary lower frames **124** are designed to handle or accommodate the building of substantially all passenger vehicles. In an alternate example, the lower frames would be standard or non-model specific for other products that may have options or variations that can be ordered by customers.

As best seen in FIGS. **3A**, **B**, **5**, **67**, an exemplary pair of upper frames **130** is illustrated. Each upper frame **130** is preferably precisely fabricated to small or close tolerances and mounted atop a respective lower frame **124** as generally shown (one described hereafter for convenience). Upper frame **130** includes vertical legs and an elevated floor **136** longitudinally extending along and parallel to path **60** forming a rigid scaffold-like assembly frame. Floor **136** is of a width **140** which is preferably about 60 inches. Other widths **140** and dimensions of upper frame **124** suitable for the application and known by those skilled in the art may be used. Precision-machined mounting surfaces (not shown) provide mounting points for assembly tools, for example programmable robots, although other assembly equipment and/or tools may be used.

In the example illustrated, preferably three inverted multi-axis industrial robots **150** attach to the underside of floor **136** and extend down below floor **136** as generally shown. The

upper frame **130** precision mounting surfaces accurately and precisely position the robots **150** relative to the upper **130** and lower **124** frames and assembly cell center point **260** providing a high level of dimensional and locational predictability and repeatability in the initial installed position and orientation of robots **150** with respect to the assembly cell for programming and operation. Alternately, precision located mounting holes are provided in the upper frames **130** to accept modular robot mounting plates (not shown). The mounting plates, for example, can be connected to the robots at the integrator's (i.e. vendor/supplier) facility with easy and precise connection to the upper frames **130** when installed in the assembly plant.

In a preferred example not shown, tapered locating pins may be installed on the upper portions of the lower frame **124** and coordinate with apertures or other details in the mating upper frame **130**. The tapered locating pins may be used to guide and position the upper frame **130** into 3-dimensional X, Y and Z precision location relative to the lower frame **124** and then secured in place with large bolts, other fasteners or other securing methods known by those skilled in the art.

Lower **124** and upper **130** frames are preferably made from welded steel elements although other materials known by those skilled in the art may be used. It is understood that lower **124** and upper **130** frames may take other sizes, shapes and configurations than that shown consistent with the above description as known by those skilled in the art.

As best seen in FIGS. **2** and **3A**, **B**, the power and controls for each robot **150** are preferably housed in control cabinets **160** secured to upper frame floor **136** as generally shown. Other positions of the cabinets **160** suitable for the application and number of robots **150** (or other assembly tools and equipment) for a particular assembly cell **56** known by those skilled in the art may be used.

Referring to FIGS. **4-8**, an example of a modular application equipment (AE) pallet or support **170** is illustrated (three (3) shown in FIG. **5**). As best seen in FIG. **5**, in the example, AE pallet **170** includes a mounting surface or top **174** having a width **176** and vertical joists or supports **180** (three shown per pallet) as generally shown. AE pallets **170** may include a bottom **182** forming a rectangular pallet-like structure. AE pallet may further include a back panel (not shown) and a front panel (not shown). Although mounting surface **174** is shown as a top or upper surface, it is understood other mounting surfaces, configurations and orientations known by those skilled in the art may be used.

In the exemplary AE pallet **170**, mounting surface **174** is a rigid panel having a plurality of through holes or slots, mounting bosses, weld nuts and/or other features for mounting application equipment (AE) **190** suitable for the assembly operations in the assembly cell **56** and most preferably for a particular assembly tool, for example a robot **150**. For example, mounting surface **174** can be a rigid steel plate with holes positioned in a 100 millimeter grid pattern for ease of positioning and securing all types of AE devices **190**. In a preferred example, where three (3) inverted robots **150** are connected to upper frame **130**, three (3) AE pallets **170** are preferably used providing the respective AE device **190** needed to support the respective robot **150** assigned an assembly task. As seen in FIG. **5**, three (3) different forms of AE devices **190** are illustrated. In the middle AE pallet **170**, a fluid storage and dispensing system **194** is secured to top **174** as generally shown. Consumable fluid materials such as sealants, adhesives, coolants and lubricants are common in vehicle body assembly lines. Although not

necessarily consumable, coolant or lubrication fluids such as water are considered consumable materials for purposes of the invention.

The far right AE device **170** has a consumable materials fastener feeder **198** connected thereto. Such fastener feeders may include consumable rivets, weld studs, weld nuts, screws and other fasteners common to vehicle body operations known by those skilled in the art. The far left AE support **170** includes a third application equipment, for example a welding controller for a resistance spot welding of aluminum application. Other AE devices **190** needed to support common vehicle body (or other product) assembly operations may include equipment necessary to support welding operations including, but not limited to, resistance spot, seam, laser, brazing, piercing and clinching operations. Examples of consumables for seam or brazing operations may include welding wire or electrodes that are selectively fed by a feeder to the assembly tool in the assembly station as further described below. It is understood herein that reference of supply of consumable or other materials from the AE devices to the assembly tool, for example a robot, also includes the supply to any end effector or other tool connected to the assembly tool. Other AE devices **190**, and consumable materials used thereby, known by those skilled in the art may be packaged and secured to a respective AE pallet **170**. Although described as useful with robots **150**, it is understood that AE devices **190** can be used with other assembly tools and equipment needed to support assembly and manufacturing line processes and operations known by those skilled in the art.

Referring to FIGS. **5** and **6**, one example of an AE pallet connector **186** is illustrated. In the example, AE pallet **170** includes hooks **188** rigidly mounted to two or more vertical supports **180** as best seen in FIG. **6**. Exemplary hooks **188** laterally extend outward from vertical supports **180** and engage cooperating structures, for example slots **144** in a laterally outward facing surface **142** of upper frame **130** forming a localized lateral continuation of floor **136** as best seen in FIG. **7**. Alternately, the coordinating mounting holes may be in the floor **136**.

Referring to FIG. **9**, an alternate example of mounting AE pallet **170** to upper frame **130** is shown. In the example, AE pallet **170** is mounted atop upper frame floor **136** through mechanical fasteners as generally shown (space shown between **170** and **136** for ease of illustration). In this configuration, the width **140** of upper frame **130** may be increased (not shown) to accommodate the width **176** of AE pallet **170** while allowing adequate space for walkway **210** as described below. Other structures, orientations and fastening methods for removably mounting AE pallets **170** to upper frame **130** known by those skilled in the art may be used.

In the examples, AE pallet **170** is configured to form a pallet-like support structure for any AE device **190** to provide consumable materials, other materials, or services (for example electrical power, fluids or data) to the assembly line, preferably adjacent exemplary industrial robots **150**. In a preferred example, pallet **170** width **176** is approximately 36 inches. In a preferred example, the combined widths **140** of upper frame **130** floor **136** and width **176** of AE support are less than 96 inches which is the standard width of a commercial boxcar shipping container. Other widths **140** of floor **136** and AE pallet **170** may be used to suit the particular application and assembly line environment. It is also in the scope of invention that the widths can comprise two or more pieces for ease of shipping and then assembled at the system integrator or on site at the assembly facility.

The exemplary pallet **170** is preferably configured, oriented and adapted to be lifted, carried and elevated by a forklift common in assembly plants. In one exemplary use, the modular AE pallets **170** are shipped "empty" to a supplier/vendor responsible for providing AE devices **190** to support assembly operations in one or more assembly cells **56** along one or more assembly lines **38-45**. The vendor can design and package the AE devices **190** in the space provided by the modular pallet **170**, securely mount the AE device **190** to the top **174** and fully test and commission the operation of the equipment at the supplier's facility thereby providing tested and ready to use equipment on installation at the assembly plant. It is understood that AE devices **190** may be mounted in other orientations with respect to pallet **170**, for example connected to the underside of top surface and extending downward. Other mounting and orientations of AE devices **190** to pallets **170** known by those skilled in the art may be used.

As best seen in FIGS. **4 A-D**, the modular design of AE pallets **170** provides for several configurations depending on the assembly operations for a particular assembly station **56**. As best seen in FIGS. **3A** and **4 A-D**, where an AE pallet **170** and AE device **190** is desired to be installed to upper frame **130**, a safety rail **146**, normally installed to upper frame surface **142** or floor **136**, is simply disconnected from upper frame floor **136** and mounted to rail connection points (not shown) on AE pallet **170** as generally shown. Securing AE pallets **170** and reconfiguring the AE devices **190** for assembly cell **56** can be done in a matter of minutes versus hours or days with conventional assembly systems.

Referring to FIGS. **5**, **7** and **8**, an example of a conduit **200** is shown. Conduit **200** includes one or more of cables, wiring harnesses and/or pipes, **202**, **204** and **205** positioned between the AE devices **190** and the assembly cell are shown. In the example, conduit **200** may be a single or multiple conduits/cables/pipes **202**, **204** and **205**, used to route, for example, an electrical and/or data cables **202** for the transfer of electrical power and information data from the control cabinets **160** to supply the necessary electricity and data to the AE devices **190** to, for example, power a fluid distribution pump **194** to supply pressurized adhesive or sealer to robot **150** or other assembly tools or cell equipment. As best seen in FIG. **8**, conduit **200** may include a cable **204** connected between the AE device **190** and the assembly tool exemplary robot **150** to provide consumable materials and other materials, data and services to the assembly tool robot in order for the robot to perform the predetermined and preprogrammed assembly tasks in coordination with the application equipment **190** in the assembly cell.

In a preferred example, where a robot **150** uses consumable materials, for example rivets, screws, or weld studs, to perform the predetermined assembly task, conduit **200** may include a pipe **205** is connected to the AE device **190** and routed through or around the AE pallet **170**, under upper frame **130**, through or around robot wrist **152** to the end effector **156** for the routing of consumable materials to assist assembly operations for that particular assembly tool. For example, it is common along vehicle body assembly lines to install adhesives, sealants and weld studs to the partially completed vehicle body in assembly cell **56**. Where a robot **150** is tasked with welding operations, the fluid dispensing system **194** may provide water or other fluids to cool the equipment for continuous operation. Additional AE devices may be installed on the same AE pallet to further support, for example, a seam welding robot through feeding of consumable welding electrode through conduit **200** to support the

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welding operation. It is understood that conduit **200** could be a pipe or casing separate from the individual cables/wires and pipes described above, or may simple be the cables/wires and pipes themselves.

In the example where an AE pallet **170** includes fastener AE devices **190**, conduit **200** may include hoses or pipes for the transport of fasteners into the assembly cell. In a preferred example, AE pallet **170** includes one or larger routing apertures (not shown) in top **174** and open face **178** for the ease of routing conduit **200** laterally toward upper frame **130**. The assigned robot **150** or other assembly cell tools would include the appropriate coordinating and reciprocal connectors so conduits **200** and/or **202**, **204** and **205** can be rapidly connected for communication of consumable materials, data and other items on installation of the modular AE pallet **170** to upper frame **130** as described. Other communication lines, conduits and routing techniques and connections known by those skilled in the art may be used. For example, the conduit **200** may simply be routed around the AE pallet floor versus through apertures in the floor as described.

It is understood that conduit **200** may come installed with the AE pallet and AE device as transferred into the assembly facility or may be largely, if not wholly installed in the assembly station. In the latter example, the AE device **190** may have a short conduit or simply connectors on the AE device **190** so it can be rapidly connected and placed in communication with the assembly cell control cabinet and/or the assembly tool in the manners described. In combination of conduits **200** is also contemplated. For example, both the assembly station and AE device may have a conduit with coordinating connectors which are engaged on installation of the AE pallet to the frame. It is also contemplated that the AE pallet **170** comes "pre-wired" and includes coordinating connectors on the pallet **170**. For example, the pallet **170** may have common connectors or a bank of plugs wherein the AE device plugs into the pallet **170**. On installation of the AE pallet to the assembly frame, wires/cables and pipes preinstalled in the assembly station are routed and plugged into another bank of connectors/plugs which place the AE device **190** in communication with the assembly tool and control cabinets in the manners described. Other structures and methods of connecting the AE pallet and AE device in communication with the assembly station known by those skilled in the art may be used.

There are numerous advantages to the modular AE pallet system as described and illustrated. For example, if the mounted first AE device **190** fails and it is too time consuming or costly to repair or replace the first AE device **190** on site at the assembly line, the entire first pallet **170** can be disconnected and replaced with a replacement first modular pallet **170** with a pre-installed and tested replacement first AE device **190** with minimal assembly line downtime and logistical disruption. This modularity and plug and play connectively will greatly reduce critical downtime of the assembly line for repairs, replacement and time consuming maintenance of application equipment **190**.

The modularity also is a major advantage for vehicle model and other product changeovers requiring reassignment of a robot **150** assembly operation or other assembly line tools/equipment. For example, a second AE pallet **170** with a second AE device **190** suitable for the new assembly tool or operation can be quickly mounted to upper frame **130** through a forklift or existing gantry crane and connected to the retasked or new assembly tool through conduit **200** as described above. In a preferred example, the second AE pallet would be the same modular AE pallet **170** used with

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the first AE device, but having a different, second AE device **190** connected to it suitable for the alternate assembly operation by the assembly tool. It is contemplated that more than one type or form of modular AE pallet **170** may be used to accommodate the various AE devices **190** or assembly line operations.

The elevation of the application equipment **190** further removes such equipment from traditional placement on plant floor **14** and routing of the communication or support lines up to the inverted robots **150** which typically required dedicated frames to support and route the lines, for example hoses and fastener conduits.

In a preferred system **10** and application of AE pallets **170** and application equipment **190** shown in FIGS. **7**, **8** and **9**, the dimensional size of floor **136** and the placement of control cabinets **160** and application equipment **190** preferably provides for a walkway **210** along floor **136** longitudinally along upper frame **130**. In one example, this is advantageous for access and maintenance of systems in the control cabinets **160** and AE devices **190** positioned thereon or connected thereto. Further, as the AE device **190** which provides consumable items such as adhesives and fasteners to the assembly cell, these consumable materials need to periodically be replenished. Walkway **210** provides a pathway for operators (see FIG. **8**) to maneuver and restock these consumables for continuous assembly station operation. As an example shown in FIGS. **7** and **8**, a drum of fluid can be raised by a forklift and installed atop floor **136**. A dolly or cart can be used by an operator to move and replace an empty fluid storage container for a fluid dispenser **194**. Where fasteners need to be replenished, an operator can manually carry a box of fasteners and load them in the application equipment hopper for future distribution to the robot **150** by the application equipment **190** and conduit **200** as described.

Referring to FIG. **4B**, an example of a distribution deck **212** is shown. Distribution deck **212** is used to assist in the supply or replenishment of consumables, for example, adhesives, sealants, fasteners and other materials that are used by the various AE devices **190** mounted on AE supports **170**. In the example shown, deck **212** is positioned at one or both ends of an assembly line **40-45** (FIG. **1**) and has a platform which is preferably directly adjacent and at the same elevation as floor **136** of the upper frame **130** and in the exemplary AE pallet floor **174** shown in FIGS. **4**, **7** and **8**. In the example deck **212**, consumables, for example 55 gallon drums of sealant **216** for use in fluid distribution device **194**, would be raised up to platform **214** by a forklift or other device and deposited on the platform. Operators can manually, or through aid of a moving device, move by hand cart the consumables deposited on deck **212** along path **210** to the appropriate AE pallet **170** where the consumables are needed. This is very advantageous for continuous operation of the AE devices **190** and assembly station **56**. The position of the AE devices **190**, consumables **216** and workers above the assembly cell **56** for this work is very advantageous for plant logistics, efficiency and safety. Other methods of depositing the consumables **216** on platform **214** and movement along path **210** may be used as known by those skilled in the art.

Referring to FIG. **1**, in a most preferred example, a distribution deck **212** would be provided at one end of each assembly line **40-45** adjacent to the material load and sequence area **30**. In one example, distribution deck **212** may be continuous and span several or all assembly lines **40-45** or be individual to each line where consumables are needed to support assembly operations. The consumables

216 would travel the least distance from the material entry area 20 to the assembly line and thus further simplify assembly plant floor congestion and logistics. Other configurations and locations of distribution deck 212 known by those skilled in the art may be used without departing from the present invention. It is further understood that distribution deck 212 may serve other purposes than receipt of consumable materials as known by those skilled in the art.

Referring to FIGS. 10 and 11, an example of an aspect of system 10 includes modular assembly tool (AT) platforms or trays 220 to provide assembly tools or other assembly equipment, for example programmable multi-axis robots 226, additional AE devices 190 and associated accessories or devices used thereby. In one example of an AT platform 220, modular robot platforms 220 are illustrated (two shown in FIG. 10, four shown in FIG. 11) at floor level 14 of the assembly cell 56. In the exemplary AT platforms 220, a floor-positioned industrial multi-axis robot 226 having a principal axis of rotation 230 (shown in FIG. 13) is mounted to a base 236. In a preferred example, base 236 includes a base plate having precision, most preferably equally spaced, mounting points or holes 240 for mounting the robot 226. The exemplary base plate is preferably mounted to frame rails 246 that extend laterally outward from assembly path 60 as generally shown. Rails 246 preferably also include precision positioned mounting points 250, for example holes, along the length of the rails. The exemplary base plate and rail mounting points provide predetermined, highly predictable and repeatable mounting points in the Z, Y and Z dimensional coordinates for the robot relative to the rails 246.

In a preferred application, rails 246 are rigidly connected to a continuous product conveyor or other equipment positioned along the assembly line or path 60 relative to the assembly station reference point 260 as best seen in FIG. 11. Connection of the modular AT platform 220 including exemplary frame rails 246 can be made through use of rigid brackets 254 mounted in holes 252 as generally shown or other connection devices and configurations known by those skilled in the art. In a preferred example, conveyor rail holes 252 are equally spaced apart and generated with close/small dimensional tolerances for accuracy and precision mounting of the AT platforms 220. Mounting points 252 may include other structures to securely connect AT platform 220 to the conveyor or other assembly station structure for the particular application.

Although platform 220 base is shown including rails 246, it is understood that the frame or support structure can vary depending on the assembly tools and AE equipment and application. For example, support 220 may include a pallet-like structure as 170 so the AT platform 220 can be transferred and moved to the line by a forklift. The exemplary base plate may include a heavy steel plate with a grid of equally spaced holes 100 millimeters (mm) for ease of mounting the assembly tools and AE devices. The plate may be supported by rails 246 or other structures known by those skilled in the art. It is understood other platform 220 constructions to position and mount platform 220 to the conveyor or support structure 110 can be used as known by those skilled in the art.

As discussed above for the inverted robots 150, the exemplary precision base plates 236, rails 246 and mounting holes 240, 250 and 252 provide for accurate, precise and repeatable X, Y and Z coordinate dimensional positioning of the robot 226 relative to the known assembly cell center point 260 and other assembly station equipment thereby facilitating rapid placement, plug and play and programming

of the exemplary robots 226 for assembly operations once installed at the assembly plant. AT platform 220 may be connected to mounting plates that are installed in the assembly plant floor in a similar manner to those described for mounting assembly station lower frames 124 described above and below for FIG. 15.

Modular AT platforms 220 may further include the necessary control cabinets 156 to power and communicate programs and data with the respective assembly tools and AE devices 190 installed on support 220. Similar to the modular AE pallets 170 and AE devices 190 discussed above, one or more of the assembly tools, AE devices 190 and control cabinets can be pre-installed on base plates 236 and/or frames/platforms 246 at the assembly tool or other supplier's facility and be fully commissioned/tested before shipment to the system integrator or directly to the assembly plant for installation. Similarly as described for AE pallets 170, the AT platforms 220 can be pre-wired and cabled as necessary with a conduit 200 for plug and play installation and operation at the assembly facility as similarly described above. The AE devices 190 can supply consumables and other materials and functions to the assembly tools, for example robots 226, as described for AE pallets 170.

The preferably self-contained, operational and initially tested/commissioned modular AT platforms 220 and equipment thereon can be transported to the assembly line, rapidly secured and connected to the existing assembly station equipment and control system in a plug and play manner as generally described for AE pallets 170 and AE devices 190. This greatly reduces the time and effort to locate, program and calibrate the assembly tool into the assembly station for rapid, small/close dimensional tolerance production operation.

It is understood that any control cabinets and AE devices required for AT platform 220 can be mounted to the base 236 or other structure described above or can be stand alone devices that are separately and independently positioned and secured in proximity to the AT platform assembly tool. In one example where robots 226 are tasked with spot welding functions, an example of an AE device 190 can be automated weld tip dressers (not shown) precisely positioned on a larger base plate 236 or frame relative to the robot. For example, at scheduled intervals, the robots 226 can be programmed to run a maintenance cycle wherein the robots position the end effector spot weld gun weld tips in engagement with the weld tip dressers to condition the weld tips for optimum and continuous operation of the assembly cell. Other AE devices 190 discussed above, and methods of coordinating, integrating and connecting and connecting these devices with assembly tools known by those skilled in the art may be used.

Referring to FIGS. 12 and 13, another aspect of an example of system 10 includes a modular protective fence or guard 270 which assists in preventing personnel from entering assembly station 56 during operation. In the example, fence 270 includes a first frame 272 and a second frame 273 as generally shown. In a preferred example, each frame 273 and 273 includes a vertical post 274, an upper support 276, an upper rail 278 and a lower rail 280. In the example fence 270, one or more front panels 286 extending along parallel to assembly path 60 and side panels connected between the upper 278 and lower 280 rails are used. In a preferred example, each fence frame is rigidly mounted to and cantilevered from the assembly station lower 124 and upper 130 frames as generally shown. This advantageously places the lower rail 280 and side panels 290 a predetermined height 294 above the plant floor 14 negating traditional mounting

structures to the plant floor **14**. This is advantageous for faster installation, maintenance and repair and cleaning of the assembly plant floor. This is further advantageous over conventional protective guards further providing for a modular plug and play assembly system with minimal requirements or reliance on the existing assembly plant infrastructure.

Front **286** and side **290** side panels can be made from steel, aluminum or other materials, for example transparent materials like polycarbonate, forming a grating or barrier to keep personnel and objects from unauthorized entry into the assembly station. Other materials, sizes, shapes and configurations of the panels and frames known by those skilled in the art may be used.

In a preferred application of modular fence **270**, the front panel **286** is slidingly mounted in guides **296** and connected to a retractor device **300**. An example of a retractor device **300** includes an electric motor **302** mounted to upper frame **130**, a cable **304** and a stationary pulley **308** as generally shown. The retractor is selectively operable by an operator or control system (not shown) to raise the front panel from a first lower position **310** proximate floor **14** to a raised upper position **316**. Upper position **316** is preferably of sufficient height such that operators and other equipment, for example forklifts, can enter assembly cell **56** and access and move assembly tools and other equipment to and from assembly cell **56** as necessary in the normal operation of the facility.

As best seen in FIG. **12**, in an application of fence **270** with use of AT platforms **220**, the guides **296** are preferably positioned laterally outward from the assembly tool robots **226** and laterally inward from control cabinets **156** and AE devices **190** as generally shown. This provides access to the assembly tool controls and AE devices **190** to, for example replenish consumable materials provided to the assembly tools by the AE devices **190**. Other positions of fence front and side panels known by those skilled in the art are within the present invention.

In a preferred application and operation of fence **270**, the front panel **286** is normally positioned in the lower position **310** when the assembly station **56** is energized or in active assembly operations. When maintenance or access to equipment inside of assembly cell **56** is required, retractor device **300** can be engaged manually or through signals received from a local or central controller (not shown), to raise front panel **286** to the upper position **316** allowing personnel and equipment easy access into the cell **56** without the need for disassembly or partial removal/relocation of traditional protective fences or guards. It is understood that different configurations of fence **280** can be made to suit the particular assembly cell or line and known by those skilled in the art. Further, retractor **300** can take other forms and features known by those skilled in the art. For example, front panels can be manually raised and locked into place with pins or other devices and then manually lowered to continue assembly operations.

Referring to FIG. **14** a flow chart of an exemplary process **400** to build and install AE pallets **170** in an exemplary robot assembly tool application is shown. In the exemplary process, at step **410** it is determined the number and specific assembly operations that will be performed in one or more assembly stations **56**, for example exemplary vehicle body assembly operations executed by industrial robots **150** with various end effectors for a variety of assembly operations. A plurality of modular, and preferably identical, AE pallets **170** are fabricated having the structural and spatial features described in the examples above in step **420**. In step **430**, the

modular AE pallets **170** are shipped "empty" in large quantities to a respective vendor for installation of an AE device (or devices) **190** by the vendor for a particular robot **150** or other assembly tools.

In an optional step **435**, the installed AE device **190** on the modular pallet **170** is pre-wired/pre-cabled with conduit **200** including power and data communication lines **206** appropriate for the assembly station, assembly tool and/or assembly operation and mated with coordinating connectors for attachment with connectors on the control cabinets, the robots **150**, other assembly tools or other assembly cell equipment. The AE device **190** is then preferably tested/commission at the vendor or system integration to ensure proper operation before shipment to the assembly plant. In some AE devices **190**, advanced testing and pre-programming of software can be performed at the vendor with minimal or no modifications and adjustments being necessary at the assembly plant for volume production.

In exemplary step **440**, the modular AE pallet **170** and installed AE device **190** is shipped to an intermediary system integrator facility, or alternately directly to the assembly plant, and matched with the prefabricated assembly scaffold frame **120**, conveyors, non-model specific equipment, for example pre-installed robots **150**, and selected model-specific equipment assigned the assembly task supported by the application equipment **190**. The pallet **170** may be elevated into position proximate upper frame **130** and floor **136** by a forklift or other lifting mechanism. The modular pallet **170** is then engaged to the upper frame **130** in the examples described, for example engagement of hooks **188** with coordinating slots **144** in upper frame **130**.

In exemplary step **450**, the application equipment conduit **200** is routed and the prewired or pre-cabled lines **202**, **204**, **205** and/or **206** are connected to the pre-wired or pre-cabled robot **150**, control cabinets or other cell equipment for rapid install, communication and operation of the assembly cell **56**. In an optional step (not illustrated), consumables **216** are transferred to and placed on upper frame(s) **130** through distribution decks **212** to supply the respective AE devices **190** with needed materials to support the predetermined assembly operations.

In an optional step **460**, on a failure or required heavy maintenance of the AE device **190** installed on the modular AE pallet **170**, the entire pallet **170** is preferably disconnected from the control cabinet, robots and upper frame **130** and quickly replaced with another pallet **170** with replacement or alternate AE device(s) **190**. This equally applies where a product model changeover occurs and/or robot tasks changed. The existing AE pallets **170** with AE device **190** is disconnected and swapped out with an alternate pallet **170** having the appropriate AE device **190** for the new assembly task.

As described, the process **400** may equally be applied to AT platforms **220**, or the AE devices **190** used therewith as described. For example, if a robot assembly tool fails or needs heavy maintenance, the modular AT platform **220** can be disconnected and replaced with a new or alternate assembly tool and AE devices **190** as required, and connected to the conveyor or other equipment as described above. The mounting points of the base **236**, rails **246** and conveyor provide for rapid reconnection of a replacement AT platform **220** relative to the assembly station and/or assembly station reference point **260** thereby minimizing reprogramming or calibration of the new assembly tool.

Referring to FIG. **15** an exemplary method **500** of assembling or installing a modular vehicle assembly system **10** is illustrated. In the example, prefabrication of system **10**

infrastructure such as frames **120**, conveyors or transports **48**, assembly tools for example robots **150/226** and other unique tooling is assumed to be already complete, but understood can vary as known by those skilled in the art.

In an initial step not shown, the centerline of assembly line **60** is preferably determined. In one example, the centerline is determined from existing X, Y and Z dimensional coordinate reference points defined by the assembly plant. An assembly cell reference point **260** may be determined as described above.

In the example, in step **510** lower frame **124** mounting plates are secured to the assembly plant floor **14** in predetermined locations relative to the assembly line **60**, assembly center line and/or assembly cell centerpoint **260** as generally described and illustrated. In step **520**, the lower frames **124** are removably secured to the mounting plates on both sides of the assembly line path **60**. The attachment points where the lower frames attach to the floor mounting plates are preferably laterally spaced from the assembly line centerline and longitudinally positioned along the assembly line at predetermined locations. In an alternate method (not shown), the lower frames **124** are mounted to the floor at predetermined locations which then the below conveyor is positioned and mounted with respect thereto. The assembly cell reference point **260** may then be established based on the installed frame and conveyor.

In step **530** the vehicle conveyor system along assembly path **60** is installed as well as any framing needed where a return conveyor along a return upper path **84** is installed. In an optional step **535** where an overhead conveyor is used as generally shown in FIG. **3B**, a transverse tooling conveyor **112** may be installed. In a preferred example, the lower frames **124**, and conveyors **50/52/90/110** defining respective assembly paths **60/78** and **84**, tooling conveyor **112** (if an overhead conveyor system) and protective fences **280** are considered to be vehicle non-model specific equipment. In other words, these devices are preferably wholly standard and used for all vehicle models or other products to be assembled.

In exemplary step **540**, the assembly station upper frame **130** is installed and secured atop the lower frame **124**. In one example, the assembly tool industrial robots **150** and control cabinets **160** are pre-installed on the upper frame **130** as a unit by a vendor prior to delivery to the assembly cell and prior to securing it to lower frame **124**. In a preferred example, the upper frames **130**, although may all be modular, identical and standard in construction, are shipped "empty" to a vendor for installation of model-specific equipment, for example preprogrammed assembly tool robots **150** and appropriate control cabinets **160**. The vendor, similar to that described for AE pallets **170** and AE devices **190**, installs and commissions the assembly tools and/or model specific equipment on upper frame **130** (or as much as practically possible depending on the equipment and application) at the vendor or system integrator's facility prior to shipment to the assembly facility for installation into the assembly station **56** and final commission for production assembly. Alternately, the robots **150** and control cabinets **160** may be installed following installation of the upper frame **130** onto the lower frame **124** in the assembly facility or in another sequence as known by those skilled in the art.

In exemplary step **550** the AE pallets **170** with pre-installed and commissioned vehicle/product model specific AE devices **190** are transported to the assembly facility and secured to upper frames **130**, coordinated with the appropriate control cabinet, and electronically connected to the robot **150**, end effector or other assembly cell tools and

equipment as generally described above. The same or similar process would be carried out for any model specific modular AT platforms **220** for a pallet-style conveyor system (FIG. **2**) as generally described above.

In exemplary step **560**, unique vehicle or product model specific tooling trays, tooling, fixtures and other equipment are delivered and installed to complete the operational assembly station equipment.

In exemplary step **570**, any remaining protective fences **270** to accommodate the model specific equipment are installed and/or enabled. It is understood that depending on the assembly cell, part or all of the protective fence or fences **270** may be installed earlier as described or where appropriate in the cell assembly process.

Referring to FIG. **16** another exemplary aspect of the invention is illustrated. In FIG. **16** an exemplary process, business method or solution **600** for purchasing/sourcing, fabricating and installing equipment for a vehicle body or other product assembly line is illustrated. The exemplary process is particularly useful with the modular system **10** described above, but may be used with other assembly operations for other products. It is understood the method **600** can be used for products other than vehicle body assembly as known by those skilled in the art.

In the example, step **610** establishes high level assembly plant parameters including plant size and target vehicle (or other product) throughput (vehicles/products per hour, shift, week and/or month or other periods or variables).

In step **620**, the assembly plant is preferably simulated three-dimensionally through CAD-CAM or other simulation tools to establish the number of assembly lines and throughput and/or efficiency of each individual assembly line. It is understood this step could be done manually or through other conventional processes and mechanisms known by those skilled in the art.

In step **620**, the assembly operations and equipment necessary for completing the assembly tasks are determined for each assembly line **40-45**. For each assembly line, the equipment is initially determined to be vehicle/product non-model specific or vehicle/product model specific. In the example, equipment is vehicle non-model specific if the equipment is useful in assembly regardless of which vehicle model or body style is being assembled. An example of vehicle non-model specific and model specific for the described system **10** is:

Vehicle Body Non-Model (NM) Specific:

- Conveyor (overhead-style **90** or pallet-style **106**);
- Both along assembly path **60** and any return path **84**;
- Base conveyor pallets **106** or suspended carriages;
- Component and subassembly delivery devices (in system **10** provided by carts **62** or carriage racks **94**);
- Generic/standard component trays, for example steel panels with precision cut holes in a 100 millimeter (mm) grid pattern for precision positioning and securing model specific detail fixtures or holders for individual components or subassemblies to be assembled;
- Lifting mechanisms within assembly cell for use with pallets or suspended carriages;
- Buffer conveyor zones along and/or laterally between assembly lines;
- Lower **124** and upper **130** assembly cell frames (without robots **150** or control cabinets);
- Frame **54** for return conveyor along path **84**;
- Carriage/pallet elevator device to move from lower path **60** to upper path **84**;
- Transverse tooling conveyor **112**;

Robots **150/226** that are not preprogrammed for particular assembly operations;

Modular AE pallets **170** (without application equipment **190**);

Distribution decks **212**;

Modular AT platforms **220** (without robots or control cabinets or accessories); and

Partial or all protective fencing **270**.

Vehicle Body Model Specific (MS):

Unique tooling and fixtures for conveyor suspended carriages and pallets;

Unique tooling and fixtures for to-be-assembled component panels/trays

Unique tooling and fixtures for transverse tooling conveyor **112**;

Robots **150/226**, robot controls and control cabinets **160** and preprogrammed and stored software for particular assembly tasks/operations;

Robot end effectors **156**;

Any portion of conduit **200** including pre-plumbing, wiring, cables, pipes and connectors of robots/assembly tools to accept and connect to AE devices **190** and consumable materials;

AE devices **190**; and

Any portion of conduit **200** including pre-plumbing/wiring, cables, pipes and connectors on AE pallet **170** and AT platforms **220**.

It is understood that variations whether equipment is initially designated as non-model specific or model specific may occur depending on the product, assembly application and operations within an assembly cell.

In step **630**, in a preferred example, the non-model specific equipment is placed out for competitive bid contract and awarded to a single or minimum number of vendors. In the example for system **10**, all vehicle non-model specific assembly equipment for all assembly lines may be sourced to one vendor. This is possible in part as the non-model specific equipment is standard and/or modular and at least partially pre-designed. This reduces and minimizes prior processes which took months and months to largely, if not wholly, custom design the non-model specific infrastructure and equipment for every assembly plant. In system **10**, since the non-model specific equipment is preferably modular and predesigned, the process to bid and award happens far more quickly than the conventional process.

At this optional point in time for step **635**, fabrication can begin on the system **10** modular non-model specific infrastructure and equipment.

In step **640**, based on the predetermined and preferably already designed modular, non-model specific equipment, the vehicle model specific assembly equipment is specified and competitively placed out for supply bid contract. In a significant advantage over conventional processes, the bids for the model specific equipment can go out much faster, possibly many months faster, as the non-model specific designs, or a great many portions thereof, are already complete. In one example in step **640**, supply contracts for the model specific equipment for each assembly line **40-45**, or combinations of assembly lines, may be awarded to other integrators/vendors. During this period **640**, the non-model specific equipment is already partially or wholly awarded and preferably fabrication already underway.

In a preferred example of step **640**, each winning model specific vendor would be responsible for the required product throughput performance for the awarded lines. It is understood that steps **635** and **640** can occur simultaneously

or even switched depending on how long the lead times are for effective management of the quotation process.

In exemplary step **650**, the awarded model specific equipment is designed. During this period, fabrication of the awarded non-model specific in step **635** continues. Where appropriate, in step **655** installation of the completed non-model specific equipment can occur at the assembly facility for initial commission. Where non-model specific equipment is to be delivered to the model-specific vendor, for example empty upper frames **130**, AE pallets **170** and AE platforms **220**, these can be shipped to the model specific vendors in step **660**.

In exemplary step **670**, the model specific equipment is fabricated and commissioned/tested. In a preferred example respecting upper frames **130**, AE pallets **170**, AE supports **220** and necessary AE devices **190** are installed, wired and plumbed with the appropriate cables and harnesses and tested at the vendor's facility as generally described above.

In exemplary step **680** the tested vehicle model specific equipment arrives and is installed at a system integrator or directly at the assembly plant. In the example of the AE pallets **170** with installed AE devices **190**, the AE pallets are lifted into position and quickly secured to upper frame **130** as previously described. The conduit **200**, which may include one or more of **202**, **204**, **205** and **206** are quickly and readily connected to the control cabinets, robot **150** (or other assembly tools or equipment) and coordinated with the equipment in the assembly station for rapid and already proven operability avoiding many problems and delays in conventional systems. This similarly occurs for modular AT platforms **220** as previously described. Other model-specific equipment is fabricated, tested and installed in the same manner. If the particular assembly plant or equipment warrants it, the fabricated modular upper frame **130** may have been shipped to the model-specific vendor. In such an instance, the robots **150**, AE pallets **170**, AE devices **190**, and control cabinets **160** may arrive to the assembly plant and be installed as a completed unit atop the lower frames **124**. Alternately, the separate AE pallets **170** shipped to the assembly facility, but can be installed after the upper frame and robots are installed on the lower frames **124**.

In one optional step (not shown), on initial installation or once production assembly begins, for example if a particular first AE device **190** fails or needs maintenance or refurbishment, the entire first AE pallet **170** or platform **220** that the respective failed first AE device **190** or assembly tool is secured to can be quickly disconnected and removed from upper frame **130** or conveyor and replaced. In one example, new (or refurbished) and tested replacement first AE device or alternate second AE device **190** preinstalled on an alternate or second AE pallet **170** can be raised, secured to upper frame **130** and connected to the control cabinet, robot and assembly cell in a matter described above.

Once operational, in an optional step not shown the individual assembly lines **40-45** throughput requirements are monitored and enforced on an assembly line-by-line basis, and the respective equipment vendor which supplied the particular model specific line and/or equipment is held accountable to meet the predetermined performance targets, to ensure the overall assembly line and assembly plant vehicle/product throughput specification is achieved.

For all of the described and illustrated methods **400**, **500** and **600**, it is understood that additional steps, fewer steps and reordering of the above steps consistent with this technical disclosure can be made to suit the particular

application and performance specifications as known by those skilled in the art without deviating from the present invention.

Although described individually, the modular AE pallets 170, AT platforms 220 and fence 270 may all be included, or separately included in various combinations to suit the particular application, to form the system 10 structure and methods as described and/or illustrated herein.

While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiments but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims, which scope is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures as is permitted under the law.

What is claimed is:

1. A modular assembly system for use in assembling a high quantity of products along an assembly line, the system having an elongate rigid assembly frame having a longitudinal axis extending substantially parallel to an assembly line, the frame having a width defining an inboard and an outboard side relative to the assembly line, legs and an elevated floor connected to the legs and extending along the longitudinal axis, and an assembly tool positioned proximate to the assembly frame and positioned vertically lower than the frame elevated floor; the system comprising:

a plurality of modular application equipment (AE) pallets, a selected one of the plurality of AE pallets removably connected to the assembly frame proximate to the assembly tool;

a plurality of application equipment (AE) devices, a selected one of the plurality AE devices removably mountable to the selected one AE pallet prior to connection of the selected one AE pallet to the assembly frame, the selected one AE device suitable for operation of the assembly tool; and

a conduit connected to the selected one AE device and at least one of the assembly tool.

2. The system of claim 1 wherein the assembly tool further comprises a plurality of multi-axis programmable robots connected to and extending along the longitudinal axis of the assembly frame, each of the plurality of robots having a predetermined assembly operation, wherein selected of the plurality of robots are each connected to a respective one of the selected one AE device suitable for the respective robot predetermined assembly operation.

3. The system of claim 2 wherein the plurality of programmable multi-axis robots are connected to and extend below an underside of the assembly frame elevated floor, the respective robots selectively extendible toward the assembly line, the robot including an end effector connected to a robot wrist.

4. The system of claim 2 wherein the selected one AE device further comprises a predetermined consumable material suitable for the respective robot predetermined assembly operation, the AE device adapted to selectively transfer the consumable material to the respective robot through the conduit.

5. The system of claim 4 further comprising a consumable material distribution deck connected to an end of the assembly frame, the distribution deck operable to receive and support bulk quantities of the consumable material for further distribution to the selected one AE pallet connected

to the assembly frame and respective selected one AE device connected to the selected one AE pallet.

6. The system of claim 4 wherein one of the plurality of robots includes an end effector connected to a robot wrist, the conduit is positioned and extends from the AE device to the robot end effector to selectively transfer the consumable material from the AE device to the end effector.

7. The system of claim 4 wherein the consumable material comprises one of an adhesive, a sealant, a coolant, a mechanical fastener or one of a welding electrode or wire.

8. The system of claim 1 wherein the plurality of AE devices comprises a first AE device for assembling a vehicle model A and a second AE device for assembling a vehicle model B which is different from vehicle model A, the selected one AE pallet having the first AE device adapted to be switched for connection to the assembly frame with another selected one AE pallet from the plurality of AE pallets having the second AE device connected thereto when a vehicle production schedule changes from the vehicle model A to the vehicle model B.

9. The system of claim 1 wherein the plurality of modular AE pallets are of substantially the same construction, each of the modular AE pallets further comprising:

a mounting surface for supporting the selected one of the plurality of AE devices;

at least two vertical supports extending between and connecting to the mounting surface; and

at least one through aperture in the mounting surface for routing the conduit from the selected one AE device through the selected one AE pallet.

10. The system of claim 9 wherein the AE pallet further comprising a hook extending from the at least two vertical supports, the hook selectively engageable with respective apertures defined by an outboard surface of the outboard side of the assembly frame to removably connect the selected one AE pallet to the assembly frame, wherein on connection of the selected one AE pallet to the assembly frame, the selected one AE pallet mounting surface is substantially flush with the assembly frame elevated floor.

11. The system of claim 9 wherein the selected one AE pallet is positioned atop of the assembly frame elevated floor adjacent to the outboard side.

12. The system of claim 9 wherein the selected one AE device comprises one of a fluid pump, a mechanical fastener feeder or a welding electrode or wire feeder.

13. The system of claim 9 further comprising:

at least one assembly tool control cabinet positioned on the assembly frame elevated floor adjacent the inboard side of the assembly frame elevated floor;

a walkway defined along the assembly frame elevated floor width between the control cabinet and the selected one AE pallet connected to the assembly frame, the walkway operable to permit a human user to freely pass along the walkway along the longitudinal axis to provide the user access to the control cabinet and the selected one AE pallet and AE device connected to the assembly frame.

14. A modular assembly system for use in assembling a high quantity of products along an assembly line, the system comprising:

an elongate rigid assembly frame having a longitudinal axis extending substantially parallel to an assembly line, the frame having a width defining an inboard and an outboard side relative to the assembly line, legs and an elevated floor connected to the legs and extending along the longitudinal axis, and an assembly tool posi-

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tioned proximate to the assembly frame and positioned vertically lower than the frame elevated floor;

an assembly tool removably engaged to the assembly frame, the assembly tool operable to conduct a predetermined assembly operation;

a plurality of modular application equipment (AE) pallets, a selected one of the plurality of AE pallets suitable for the assembly tool and the predetermined assembly operation removably engaged with the assembly frame proximate to the assembly tool;

a plurality of application equipment (AE) devices, a selected one of the plurality AE devices suitable for the assembly tool and predetermined assembly operation removably mountable to the selected one AE pallet prior to removable engagement of the selected one AE pallet to the assembly frame;

a consumable material in communication with the selected one AE device, the consumable material suitable for the assembly tool and predetermined assembly operation; and

a conduit connected to the selected one AE device and the assembly tool, the conduit operable to selectively transfer the consumable material from the selected one AE device to the assembly tool.

15. The system of claim **14** wherein the assembly tool further comprises a plurality of multi-axis programmable robots each connected to and extending along the longitudinal axis of the assembly frame, each of the plurality of robots having a respective predetermined assembly operation, wherein each robot is connected to an AE pallet having an AE device suitable for the respective robot predetermined assembly operation removably engaged with the assembly frame adjacent the robot, the AE device operable to selectively transfer the consumable material from the AE device to the robot for the predetermined assembly operation.

16. The system of claim **15** wherein the plurality of AE devices comprises a first AE device for assembling a vehicle model A and a second AE device for assembling a vehicle model B different from vehicle model A, the selected one AE pallet having the first AE device removably engaged with

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the assembly frame adapted to be replaced with another selected one AE pallet having the second AE device connected thereto when a vehicle production schedule changes from the vehicle model A to the vehicle model B.

17. The system of claim **16** wherein the plurality of modular AE pallets are of substantially the same construction, each of the modular AE pallets further comprising:

a mounting surface for supporting the selected one of the plurality of AE devices;

at least two vertical supports extending between and connecting to the mounting surface; and

at least one through aperture in the mounting surface for routing the conduit from the selected one AE device through the selected one AE pallet.

18. The system of claim **17** wherein the AE pallet further comprising a hook extending from the at least two vertical supports, the hook selectively engageable with respective apertures defined by an outboard surface of the outboard side of the assembly frame to removably connect the selected one AE pallet to the assembly frame, wherein on connection of the selected one AE pallet to the assembly frame, the selected one AE pallet mounting surface is substantially flush with the assembly frame elevated floor.

19. The system of claim **17** wherein the selected one AE device comprises one of a fluid pump, a mechanical fastener feeder or a welding electrode or wire feeder.

20. The system of claim **17** further comprising:

at least one assembly tool control cabinet positioned on the assembly frame elevated floor adjacent the inboard side of the assembly frame elevated floor;

a walkway defined along the assembly frame elevated floor width between the control cabinet and the selected one AE pallet engaged with the assembly frame, the walkway operable to permit a human user to freely pass along the walkway along the longitudinal axis to provide the user access to the control cabinet and the selected one AE pallet and AE device engaged with the assembly frame.

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